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ABSTRACT

The skills taught in these materials for a seven-unit course were those identified as necessary not only for entry-level electronic technicians but for those in other occupations as well, including appliance repair, heating and air conditioning, and auto mechanics. The seven units are on shop orientation and safety principles, introduction to direct current, circuitry, introduction to alternating current, circuit components, basic power supplies, and semiconductor devices. The first section is designed to teach teachers how to use the materials and includes an explanation of instructional elements, an instructional-task analysis for each unit, a seven-page glossary, and a list of 14 references. The instructional elements for the units include objectives, suggested activities, information sheets, transparency masters, assignment sheets, job sheets, tests, and test answers. Some elements, such as the information sheets, include diagrams and line drawings. (CML)

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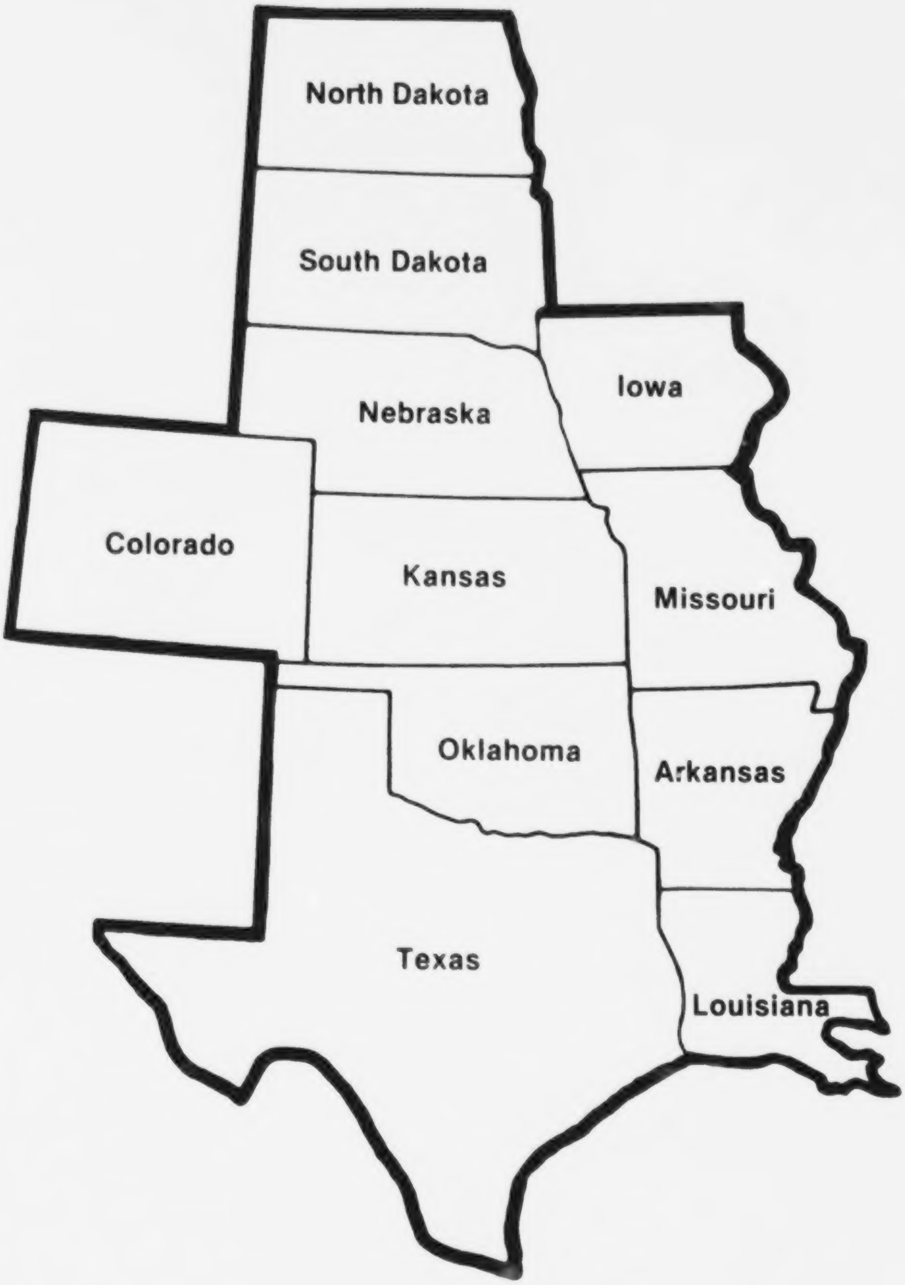
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BASIC ELECTRONICS

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BASIC ELECTRONICS

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FOREWORD

The Mid-America Vocational Curriculum Consortium has developed a total concept for electronics. This approach is designed to provide a practical and realistic approach to competency-based training materials in electronics and to provide basic electronics competencies for many other vocational programs.

Identified are those tasks that are common not only to the entry-level electronic technician but also to other vocational occupational programs such as appliance repair, heating and air conditioning, auto mechanics, etc. *Basic Electronics* therefore covers the tasks not only required of the electronic technician but also those tasks required in many other occupations. *Basic Electronics* provides the foundation and serves as a building block for progressing to a higher level of competency in many occupations.

General Electronics Technician includes those additional tasks required above *Basic Electronics* for job entry in the electronics field.

Upon completion of the *Basic Electronics* and *General Electronics Technician* competencies, students are ready for job entry or may continue their education by specializing in one of many electronics areas such as communication electronics.

Every effort has been made to make these publications basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted from the publication: motivation, personalization, and localization. These areas are left to the individual instructors and the instructors should capitalize on them. Only then will these publications really become a vital part of the teaching-learning process.

Bob Patton, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

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USE OF THIS PUBLICATION

Instructional Units

Basic Electronics contains seven units. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated

    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations

C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Answers to Assignment Sheets/Test

Answers to the assignment sheets and the test are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

BASIC ELECTRONICS

INSTRUCTIONAL/TASK ANALYSIS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT I: SHOP ORIENTATION AND SAFETY PRINCIPLES	
	1. Terms and definitions
	2. Hazards of working with electrical and electronic equipment
	3. Facts about electrical shock
	4. Treating a victim of electrical shock
	5. Types of fires
	6. Types of fire extinguishers
	7. Safety color coding
	8. General safety rules
	9. Types of hand tools and equipment
	10. Factors to consider when selecting hand tools
	11. Tool maintenance procedures
	12. Types of soldering tools
	13. Solder and flux
	14. Primary purposes for solder in electrical applications
	15. Safe soldering procedures
	16. Types of connections
	17. Types of desoldering tools
	18. Cleaners and lubricants

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

19. Prepare a soldering iron tip for use
20. Adjust wire strippers
21. Strip and tin wires for soldered connections
22. Solder wires to turret terminals, then desolder wires
23. Splice wires together by means of soldering and crimping (flat cable)
24. Repair a printed circuit board

UNIT II: INTRODUCTION TO DC

1. Terms and definitions
2. Common parameters used in electronics
3. Numerical decimal equivalents and powers of ten prefixes
4. Resistor color code
5. Determining resistance using the resistor color code
6. Basic circuit elements and their symbols
7. Types of resistors
8. Meter ranges for analog and digital meters
9. Types of meter scales
10. General steps used in preparing a multimeter for operation
11. Characteristics of meters
12. Procedures for measuring voltage
13. Procedures for measuring amperage
14. Procedures for measuring resistance

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

24. Solve problems for an unknown voltage, amperage, and resistance

25. Calculate the resistance values from given color codes

26. Read analog voltmeter scales

27. Convert amperes to milliamps and microamps

28. Read analog ammeter indications

29. Measure and compare current in a circuit at two different voltage levels

30. Wire a functional relay circuit

31. Measure the voltage drop in a DC circuit

32. Demonstrate that magnetic poles can attract and repel

33. Construct a simple electromagnet and check its operation

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

15. Amperage measurement characteristics

16. Voltage measurement characteristics

17. Ohm's Law

18. Uses of Ohm's Law

19. Magnetic properties

20. The use of the left-hand rule for conductors and coils

21. Method and effect of induction

22. Types of grounds

23. Static electricity grounds

UNIT III: CIRCUITRY

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms and definitions
	2. Voltage in a series circuit
	3. Resistance in a series circuit
	4. Current in a series circuit
	5. Voltage in a parallel circuit
	6. Resistances in parallel
	7. Current in a parallel circuit
	8. Voltage in a series-parallel circuit
	9. Steps to simplify resistance in a series-parallel circuit
	10. Current in a series-parallel circuit
	11. Characteristics of electrical power
	12. Functions of a voltage divider
13. Determine total voltage in a series circuit	
14. Determine voltage drops across resistances	
15. Determine the total resistance in a series circuit	
16. Determine current in a series circuit	
17. Determine unknown circuit values	
18. Determine unknown values in a resistive series circuit	
19. Compute the power dissipated in a resistive series circuit	
20. Calculate current and voltage in parallel circuits	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
21. Calculate resistance in parallel circuits	
22. Calculate power in parallel circuits	
23. Calculate various values in parallel circuits	
24. Trace current flow in series-parallel circuits	
25. Perform exercises in circuit reduction	
26. Solve for total resistance	
27. Solve for total current	
28. Solve for total voltage	
29. Solve for branch voltages and currents in series-parallel circuits	
30. Solve for multiple values of voltages and current	
31. Answer questions regarding opens and shorts in series-parallel circuits	
32. Answer questions about grounds and voltage polarity	
33. Analyze no-load and load circuits	
34. Verify Ohm's law	
35. Analyze a series circuit	
36. Measure voltage, current, and resistance in a parallel circuit	
37. Analyze a series-parallel circuit	
38. Construct a voltage divider and analyze its function	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT IV: INTRODUCTION TO AC

1. Terms and definitions
2. Principles of inductance
3. Principles of capacitance
4. Types of transformers
5. Power in three-phase circuits
6. Steps for identifying three-phase transformer connections
7. Formulas for converting from one AC measurement to another AC measurement
8. Phase shifting
9. Relationship between time and frequency
10. Common types of filters
11. Configurations of filters
12. Types of single-phase transformer connections
13. Measure alternating current voltages using a multimeter
14. Measure alternating current using a multimeter
15. Determine the configuration of a multiple-winding transformer

UNIT V: CIRCUIT COMPONENTS

1. Terms and definitions
2. Equipment used in measuring circuit components
3. Sensory factors in troubleshooting circuit components

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

4. Test and accept/reject, replace cells
5. Test and accept/reject, replace lamps
6. Test and accept/reject, replace switches
7. Test and accept/reject, replace resistors
8. Test and accept/reject, replace fuses and circuit breakers
9. Test and accept/reject, replace capacitors
10. Test and accept/reject, replace coils
11. Test and accept/reject replace transformers
12. Analyze the effects of temperature on a thermistor
13. Test and accept/reject, repair cables and wires
14. Test and accept/reject, replace relays
15. Test and accept/reject, replace solenoids

UNIT VI: BASIC POWER SUPPLIES

1. Terms and definitions
2. Depletion or barrier region of a P-N junction and the barrier potential
3. Biasing effects on the P-N junction
4. Diode schematic symbols
5. Reasons for diode failure
6. Rectifier circuits and output waveforms

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	7. Power supply components and their applications
	8. Basic power supply functions
	9. Voltage regulator circuit schematics
	10. Troubleshooting the basic power supply
11. Use an ohmmeter to determine the anode and cathode of diodes	
12. Check transistors for proper operation	
13. Construct and test a half-wave rectifier circuit	
14. Construct and test a full-wave bridge rectifier circuit	
15. Construct and test a capacitor filter circuit	
16. Construct and test a Pi-section filter circuit	

UNIT VII: SEMICONDUCTOR DEVICES

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Current flow in transistors
	3. Characteristics of transistor emitters, bases, and collectors
	4. Emitter, base, and collector of various transistors
	5. Characteristics of bipolar and field-effect transistors
	6. Special semiconductor devices and their applications
	7. Features of a typical dual in-line package (DIP) integrated circuit

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	8. Finding number-one pin on integrated circuits
	9. Advantages of integrated circuits as compared to discrete components in equivalent circuitry
	10. Guidelines to follow when working with integrated circuits
11. Perform a static test of semiconductor diodes	
12. Test and accept/reject, replace light	
13. Test transistors	
14. Test and accept/reject replace silicon-controlled rectifiers	

BASIC ELECTRONICS

Glossary

AC — Abbreviation for alternating current

Accident — Any unplanned event, occurring suddenly, which causes personal injury or damage to property

Accuracy — How near the instrument reading is to the actual value

Alkaline cell — Can provide up to seven times the service of a carbon-zinc cell; output voltage is 1.5 volts; can be either primary or secondary cell

Ampere — Basic unit of electric current

Analog device — Component that operates at any voltage level within a range

Applied voltage — Total voltage supplied to a circuit; also referred to as supply voltage or source voltage

Base — Control section that varies conductivity of the transistor

Battery — A group of cells connected on a series or parallel circuit

Bleeder resistor — A resistor that is placed in parallel with a capacitor in order to provide a discharge path for the capacitor when the power supply is turned off

Branch circuit — Circuit originating from a main circuit, often one of many

Break voltage — Voltage level at which a diode device will switch on and conduct current

Calibration — Technique of testing and adjusting an instrument by referencing it to another instrument or device of known accuracy and precision

Capacitance — Property of a capacitor that opposes any change in voltage

Capacitor — Device used to store electrical charge

Capacitor tester — An instrument that measures capacitance in leakage current

Carbon-zinc dry cell — Most common type of dry cell; nominal output voltage is 1.5 volts

Channel — Narrow path within a field-effect transistor through which conduction of current is controlled

Chip — Integrated circuit

Choke — A coil of wire wound around an iron core or a form of insulating material a number of times

Circuit — A system of conductors through which an electric current is intended to flow

Circuit analysis — Applying Ohm's law and other rules to determine the effect of certain parameters on circuit variables

Circuit breaker — A device designed to switch open a circuit automatically when a current overload exists; this device may be reset

Collector — Section of transistor in which majority current carriers are *collected* out of the device

Concave — Having a curved form which bulges inward

Continuity — A condition which results in a complete path for current to flow

Convex — Having a curved form which bulges outward

Counter electromotive force (CEMF) — Voltage developed in an inductor which is opposite that of the applied voltage at every instant

Crimping — Applying mechanical pressure to compress a sleeve-type or cuptype electrical terminal to ensure a good electrical connection between the sleeve and the conducting wires it contains

Cutoff — State when all normal charge carriers stop flowing in a device

Cycle — One complete set of values for a repetitive wave form

Cycling — The process by which a battery is discharged and recharged

Depletion mode — Field-effect transistor operation in which a negative voltage on the gate repels electrons in the channel and reduced conduction

Depletion region — Area within semiconductor material where charge carriers are neutralized

Dielectric — Insulating substance between plates of a capacitor

Discharge — To remove electrical energy from a charged body (capacitor or battery)

Discrete device — Component composed of one functional element as opposed to an integrated-circuit device composed of many elements

Doping — Process of adding current-conducting impurities into crystal materials to make semiconductors

Drain — Electrode of a field-effect transistor corresponding to the collector of a bipolar transistor

Dry cell — A nonrechargeable source of electrical energy produced by chemical action

Electrolytic capacitor — Capacitor that must be connected in only one direction, observing polarity

Electrolyte — A substance which, in solution, is dissociated into ions and is capable of conducting an electrical current

Electromagnet — A core of soft iron that is temporarily magnetized by sending current through a coil of wire wound around the core

Electromotive force (EMF) — Force or voltage that causes current to flow through a device

Emitter — Most heavily doped section of transistor where majority current carriers travel inward, and thus are *emitted* into the device

Enhancement mode — Field effect transistor operation in which a positive voltage on the gate attracts electrons into the channel and increases conduction

Error — How far the measurement is from the actual value

Farad — Unit of measure of capacitance

Field effect — Electromagnetic force that controls conduction in field-effect transistors

Fillet — Solder-welding two edges at right angles

Filter — A device that reduces rapid variations in voltage or current by restricting variations from the circuit, bypassing variations from the circuit or slowing rapid variations to a gradual change

Flux — Solution that cleans metals before or during soldering, or chemically acts to aid the fusion process

Frequency — The number of cycles per second for a waveform with periodic variations

Frequency response — Ability of a device to amplify a frequency without distortion or attenuation

Fuse — An overcurrent protective device with an element that melts and opens the circuit when overheated; this device must be replaced

Fusible resistor — A resistor for protecting a circuit against an overload

Galvanized — Surface on which zinc has been deposited by the process of hot dipping or electroplating

Gate — Electrode of various semiconductor devices that provide control for operation

Ground — Common return to earth for AC power lines; chassis ground in electronic equipment is the common return to one side of the internal power supply

Hardware — Circuitry, wiring, and devices of an electronic instrument or computer

Henry — Unit of measure of inductance

Hertz — Unit of frequency; one Hertz equals one cycle per second

Hybrid integrated circuit — Device in which discrete components and integrated circuits are combined into an integrated package

Inductance — Property of an inductor that opposes any change in current flow

Inductor — Device used to concentrate magnetic lines of force

Induction — Production of an electric charge or magnetic field in a substance by an electric source, magnet, or magnetic field

Input impedance — Total opposition to current at the input of a device

Insulation — A substance that prohibits flow of electricity

Integrated circuit — Device constructed of multiple segments of semiconductor materials and junctions containing the equivalent function of such discrete devices as transistor and diode junctions and resistors

Internal resistance — Total resistance offered by a device; is normally associated with the power source

Lag or lead angle — The relative displacement between voltage and current waveforms measured in degrees; one cycle is 360°

Land — Printed wiring attached to the surface of a printed circuit board

Lead-acid wet cell — Most commonly used for automobile battery; nominal output voltage is 2.1 volts; can be constructed in combinations of three (6 volt) or six cells (12 volt) batteries; lead-acid is a secondary cell and can be recharged

Leakage current — Undesirable current flow between capacitor plates due to inability of dielectric material to restrict that flow

Linear device — Component that has the same gain or reaction to the input over the operating range regardless of frequency or environmental factors such as temperature and humidity

Lithium cell — Has high output voltage, long shelf life, low weight, and small volume; output voltage is either 2.9v or 3.7v, depending on the electrolyte; shelf life is ten years or more

Magnet — An object which will attract iron, nickel, or cobalt and which will produce an external magnetic field

Magnetic field — The area around a magnet through which the lines of force flow

Magnetic switch — A solenoid which performs a simple function, such as opening or closing a switch

Magnetism — A property of certain materials which exerts a mechanical force on other materials and which can cause induced voltages in conductors when relative movement is present

Majority current carriers — Holes in the p-type semiconductor and electrons in the n-type semiconductor that transfer most of the current within a type of semiconductor material

Monlithic integrated circuit — Device in which active elements (such as transistors) and passive elements (such as resistors) are integrated into a continuous single component on a single substrate

Multimeter — Instrument capable of measuring "multiple" of values

Node — A junction point in a circuit at which current divides into separate branches, or reunites from separate branches

Ohms — Unit of measure for resistance

Open (open circuit) — A condition that occurs when a circuit is broken (broken wire or open switch) that interrupts current flow

Open circuit — A circuit with no available path for current to flow (infinite resistance)

Output impedance — Total opposition to current at the output of a device

Oxides — Films and impurities which form on the surface of metals when exposed to air or water and which, if not cleaned off, will prevent a good bond between the surfaces and solder

Pad — Round terminal connection point on a printed circuit board where component lead wires are attached

Parallel circuit — An electronic circuit which provides more than one path (or branch) for current to flow

Parameter — A specified element or condition which determines the value of circuit variables

Period — The amount of time for one cycle

Phase — Source of AC power; a relationship between time and AC wave form or between AC wave forms

Phenolic board — Plastic material (thermosetting resin) which becomes permanently hardened when subjected to heat; originally known as Bakelite®; used for printed circuit board construction

Pinch-off voltage — Voltage from the gate to the source of field-effect transistors at which condition of current ceases

Potential difference — The electromotive force developed between two points that moves electric current through a load that is connected across a source

Power — The rate of doing work

Power supply — Circuit or device that provides a specific electrical output by transforming a different electrical input or converting other forms of energy

Primary cell — Battery that can not be recharged

Printed circuit board — Plastic, fiberglass, or phenolic board upon which copper strips interconnect between mounted components

Range — Establishes the limits of a scale

Reactance — Measure of AC opposition offered by components such as capacitors and inductors; measured in units of ohms

Regulator — Circuit or device that serves to keep voltage or current output at a constant level

Relay — An electrical switch which opens and closes a circuit automatically

Resistance — Opposition to current

Resolution — How well the instrument will indicate a small change in the measured value

Ripple — Low-amplitude variation of DC power; usually results from insufficient filtering of rectified AC

Rosin — A material obtained from pine trees which is used during soldering to help ensure a good bond between the solder and the metal surfaces

Run — Strip of conductor on a printed circuit board

Safety — The state of being free from danger, personal risk, or injury

Saturation — When an increase in collector voltage no longer causes an increase in collector current and with an increase in base current it no longer causes an increase in collector current

Secondary cell — Battery that can be recharged

Self-inductance — Conductor's ability to induce voltage in itself when current changes

Sensitivity — How well an instrument responds to small measurements of small changes in the value being measured

Series circuit — A circuit where the same current passes through each component

Series-parallel circuit — A circuit that contains some components in series and some in parallel

Series regulator — Controller placed in line with the load; controls by varying resistance to the load current

Shelf life — Length of time a component can be stored before its operating characteristics start to degrade

Short (short circuit) — A condition that occurs when a circuit comes into contact with another part of the same circuit, causing a change in either circuit resistance or current

Short circuit — An abnormal connection of relatively low resistance between two points of differing potential in a circuit

Shrink tubing — Plastic insulating sleeve which shrinks in diameter with the application of heat to form a seal

Shunt — Circuit that bypasses another circuit or device, especially a low-resistance bypass for an ammeter circuit

Shunt regulator — Controller placed in parallel to the load; bypasses excessive current and varies total current through a series resistance to control output voltage

Solder — Soft metal alloy of tin and lead used for plating or fusing metals together

Solder joint — Junction of two or more metals fused with solder

Solenoid — An electromagnet consisting of a coil with a moveable core; as current flows through the coil, the core moves, performing a mechanical action

Source — Electrode of a field-effect transistor corresponding to the emitter of a bipolar transistor

Splice — To unite (connect) two wires to form a continuous length

Static electricity — The storage of electrical energy

Stripping — Removing insulation from electrical conductors

Substrate — Base material of an integrated-circuit chip upon which the circuitry is formed

Switch — A mechanical or electrical device which breaks or completes a path for electrical current or routes it over a different path

Tank circuit — An inductor and capacitor in parallel

The reciprocal of a number — One (1) divided by that number

Thermistor — A temperature-compensating resistor where the resistance varies with the temperature

Time constant — Time required for a capacitor or inductor to change by 63% after a sudden rise or fall in voltage or current

Tinning — The application of a small amount of solder to surfaces to be soldered to help ensure good wetting during soldering

Tolerance — The acceptable amount of variation from an indicated value

Transistor — Solid-state semiconductor device usually having three terminals; varies conductivity according to voltage and current inputs

Trigger — Electrical impulse used to turn devices on and off

Variable — Changeable or capable of being changed

Volt — The unit of measurement of electromotive force

Voltage — Electrical force or pressure that causes the flow of electrical current (electrons)

Voltage drop — Difference in voltage measured across a component in a circuit

Watt — Unit of measure for power

Wetting — The ability of molten solder to flow over and fuse completely with the metal surfaces to which it is applied

Wicking — Flow of solder under the insulation of covered wire

Work — Amount of energy used in a specified time

BASIC ELECTRONICS

References

(NOTE: The following is an alphabetical list of references used in completing this text.)

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SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify hand tools and equipment used in basic electronics, apply general safety rules and procedures, and prepare and use a soldering iron. Competencies will be demonstrated by correctly performing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to shop orientation and safety principles with their correct definitions.
2. List six hazards of working with electrical and electronic equipment.
3. Complete statements concerning facts about electrical shock.
4. Select true statements concerning treating a victim of electrical shock.
5. Match types of fires with their descriptions.
6. Match types of fire extinguishers with their uses.
7. Match safety colors with the types of hazards they designate.
8. Select true statements concerning general safety rules.
9. Identify types of hand tools and equipment.
10. Match hand tools and equipment with their uses.
11. Select true statements concerning factors to consider when selecting hand tools.

OBJECTIVE SHEET

12. Complete statements concerning tool maintenance procedures.

13. Match types of soldering tools with their uses.

14. Select true statements related to solder and flux.

15. List primary purposes for solder in electrical applications.

16. Arrange in order safe soldering procedures.

17. Distinguish between types of connections.

18. Select true statements concerning types of desoldering tools and their processes.

19. Complete a chart of cleaners and lubricants.

20. Demonstrate the ability to:

    a. Prepare a soldering iron tip for use. (Job Sheet #1)

    b. Adjust wire strippers. (Job Sheet #2)

    c. Strip and thin wires for soldered connections. (Job Sheet #3)

    d. Solder wires to turret terminals, then desolder wires. (Job Sheet #4)

    e. Splice wires together by means of soldering and crimping. (Job Sheet #5)

    f. Repair a printed circuit board. (Job Sheet #6)

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate the proper use of all hand tools.
2. Make students aware of the various types of tools which are available but are not listed in the information sheet.
3. Invite a fire department representative to class to demonstrate the proper use of fire extinguishers.
4. Invite a Red Cross representative to class to demonstrate first aid and CPR techniques.
5. Obtain and show film about static electric discharge.
6. Demonstrate proper tinning of soldering iron tip to class.
7. Demonstrate proper tinning of stranded wire conductors.
8. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

CONTENTS OF THIS UNIT

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM 1 — Electric Shock vs. Body Sensation
2. TM 2 — Hand Tools
3. TM 3 — Hand Tools (Continued)
4. TM 4 — Hand Tools (Continued)
5. TM 5 — Hand Tools (Continued)
6. TM 6 — Hand Tools (Continued)
7. TM 7 — Hand Tools (Continued)
8. TM 8 — Hand Tools (Continued)
9. TM 9 — Types of Soldering Tools
10. TM 10 — Soldered Connections (No Mechanical Security Prior to Soldering)
11. TM 11 — Soldered Connections (With Mechanical Security Prior to Soldering)
12. TM 12 — Types of Desoldering Tools

E. Job sheets

1. Job Sheet #1 — Prepare a Soldering Iron Tip for Use
2. Job Sheet #2 — Adjust Wire Strippers
3. Job Sheet #3 — Strip and Tin Wires for Soldered Connections
4. Job Sheet #4 — Solder Wires to Turret Terminals, Then Desolder Wires
5. Job Sheet #5 — Splice Wires Together by Means of Soldering and Crimping
6. Job Sheet #6 — Repair a Printed Circuit Board

F. Test

G. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

(NOTE: The following is a list of references used in completing this unit.)

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co.

B. New Mexico Vocational Industrial Safety Guide. Santa Fe, NM: New Mexico State Department of Education.

C. Robertson, L. Paul. *Basic Electronics I (Revised Edition).* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

D. Siebert, Leo N. *Introduction to Industrial Electricity-Electronics.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1981.

E. Villanucci, Avtgis, and Megow. *Electronic Techniques — Shop Practices and Construction.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 1974.

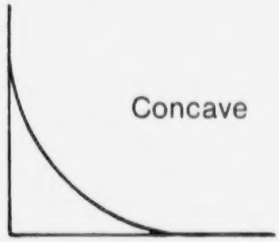
SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

INFORMATION SHEET

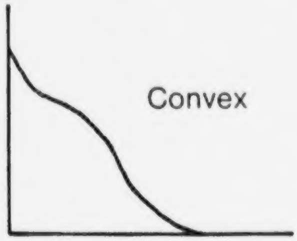
I. **Terms and definitions**

A. Accident — Any unplanned event, occurring suddenly, which causes personal injury or damage to property

B. Concave — Having a curved form which bulges inward



C. Convex — Having a curved form which bulges outward



D. Crimping — Applying mechanical pressure to compress a sleeve-type or cuptype electrical terminal to ensure a good electrical connection between the sleeve and the conducting wires it contains

E. Fillet — Solder-welding two edges at right angles

F. Flux — Solution that cleans metals before or during soldering, or chemically acts to aid the fusion process

(NOTE: There are many types of fluxes for different types of soldering and welding. Fluxes perform different jobs for various purposes and applications. Do not use unspecified fluxes on any application.)

G. Galvanized — Surface on which zinc has been deposited by the process of hot dipping or electroplating

INFORMATION SHEET

H. Land — Printed wiring attached to the surface of a printed circuit board

I. Oxides — Films and impurities which form on the surface of metals when exposed to air or water and which, if not cleaned off, will prevent a good bond between the surfaces and solder

J. Pad — Round terminal connection point on a printed circuit board where component lead wires are attached

K. Phenolic board — Plastic material (thermosetting resin) which becomes permanently hardened when subjected to heat; originally known as Bakelite®; used for printed circuit board construction

L. Printed circuit board — Plastic, fiberglass, or phenolic board upon which copper strips interconnect between mounted components

M. Rosin — A material obtained from pine trees which is used during soldering to help ensure a good bond between the solder and the metal surfaces

N. Run — Strip of conductor on a printed circuit board

O. Safety — The state of being free from danger, personal risk, or injury

P. Shrink tubing — Plastic insulating sleeve which shrinks in diameter with the application of heat to form a seal

Q. Solder — Soft metal alloy of tin and lead used for plating or fusing metals together

(NOTE: Solder is available in many forms, including solid wire, wire with paste, flux, bars, and washers. Sometimes solder includes other metals, such as silver, gold, or cadmium.)

R. Solder joint — Junction of two or more metals fused with solder

S. Splice — To unite (connect) two wires to form a continuous length

T. Stripping — Removing insulation from electrical conductors

U. Tinning — The application of a small amount of solder to surfaces to be soldered to help ensure good wetting during soldering

V. Wetting — The ability of molten solder to flow over and fuse completely with the metal surfaces to which it is applied

(NOTE: Dirt, grease, and oxides prevent good wetting during soldering.)

W. Wicking — Flow of solder under the insulation of covered wire

INFORMATION SHEET

II. Hazards of working with electrical and electronic equipment

A. Electrical shock

(NOTE: Electrical shock can occur if the body contacts an electrical circuit or is struck by lightning. It can cause serious burns and muscle damage, and can kill a victim by stopping the heart or breathing, or both.)

B. Electrical burns

(NOTE: Electrical burns can occur if the body contacts an electrical circuit or is struck by lightning, or if the body is exposed to radio-frequency waves, X-rays, or other forms of radiation.)

C. Electrical fires

(NOTE: Electrical fires can occur if electrical wires become heated because of an overloaded circuit and contact flammable materials.)

D. Injury from misuse of tools

(NOTE: Personal injuries can be caused by the improper use of tools.)

E. Chemical burns or poisoning

(NOTE: Some chemicals used as cleaners or lubricants can be hazardous if ingested. Always wash hands thoroughly after direct contact and read the labels for special handling instructions.)

F. Gas inhalation

(NOTE:Electronic components exposed to high amounts of heat or current may burn and produce gases that if directly inhaled may cause irritation of the lungs and respiratory system.)

III. Facts about electrical shock

A. Current is usually considered more dangerous than voltage.

B. High voltage (low current) tends to knock the victim away from the circuit, minimizing exposure time.

C. High current tends to cause the body to adhere to the circuit, so that the victim cannot let go. (Transparency 1)

1. At about 1 milliampere (0.0010 amperes), a slight shock will be felt.

2. At about 10 milliamperes (0.010 amperes) the shock is severe enough to paralyze muscles, but a person may be able to let go of the conductor.

INFORMATION SHEET

3. At about 100 milliamperes (0.1 amperes) the shock is usually fatal if it lasts for one second or more.

   (NOTE: Human body resistance varies from about 500,000 ohms when dry to about 300 ohms when wet. Because of this, voltages as low as 30 volts can cause enough current to be fatal. Any circuit with a potential of at least 30 volts must be considered dangerous.)

IV. Treating a victim of electrical shock

A. Safely remove the victim from contact with the source of electricity using the following procedure:

   (CAUTION: Do not touch the electrical circuit or the victim unless the power is off or you are insulated.)

   1. Turn off the electricity by means of a switch or circuit breaker or cut cables or wires by means of a wood-handled axe or insulated cutters if available.
   2. Use a dry stick, rope, leather belt, coat, blanket, or any other nonconductor of electricity to separate the victim from the electrical circuit.

B. Call for assistance.

   1. Others in the area may be more knowledgeable than you about treating the victim.
   2. Another person can call for professional medical help while you administer first aid.

C. Check victim's breathing and heartbeat.

   (NOTE: **TIME IS LIFE AT THIS POINT!**)

   (CAUTION: Mouth-to-mouth resuscitation and cardiopulmonary resuscitation can cause more harm than good to a victim unless the person administering the first aid has been trained in the proper procedure.)

   1. If pulse is detectable, but breathing has stopped, administer mouth-to-mouth resuscitation until medical help arrives.
   2. If heartbeat has stopped, administer cardiopulmonary resuscitation, but only if you have been trained in the proper technique.
   3. If both heartbeat and breathing have stopped, alternate between cardiopulmonary resuscitation and mouth-to-mouth resuscitation, but again, only if you have been trained in this technique.

INFORMATION SHEET

D. Administer first aid for shock and burns as necessary.

   1. Use blankets or coats to help keep the victim as warm and comfortable as possible while waiting for help.

   2. Raise victim's legs slightly above head level to help prevent shock.

   3. If the victim has suffered burns:

      a. Cover your mouth and nostrils with gauze or a clean handkerchief to prevent breathing germs on the victim while treating the burns.

      b. Wrap burned area firmly with sterile gauze or clean linen or towels.

      (CAUTION: Do not attempt any other treatment of burns.)

E. Always continue treatment but only within your ability until medical help arrives.

V. Types of fires

A. Class A — Fires that occur in ordinary combustible materials

Examples: Wood, rags, paper, or trash

B. Class B — Fires that occur in flammable liquids

Examples: Gasoline, oil, grease, paints, and thinners

C. Class C — Fires that occur in electrical and electronic equipment

Examples: Motors, switchboards, circuit wiring, radios, and television sets

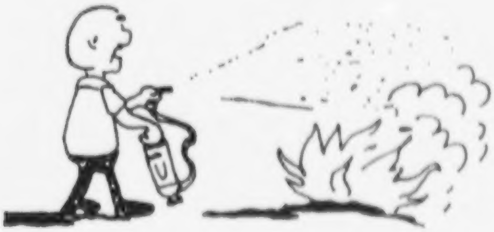
D. Class D — Fires that occur in combustible metals

Examples: Powdered aluminum and magnesium

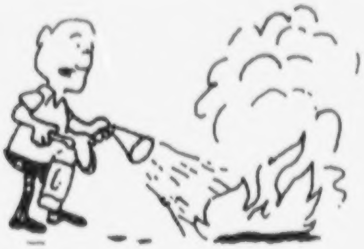
INFORMATION SHEET

VI. **Types of fire extinguishers and their uses**

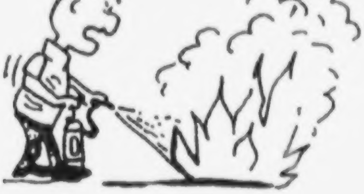
A. Foam — Instead of spraying stream into the burning liquid, allow foam to fall lightly on the fire; use for class A or class B fires.



B. Carbon dioxide — Direct discharge as close to fire as possible, first at the edge of flames, then gradually forward and upward; use for class B or class C fires.

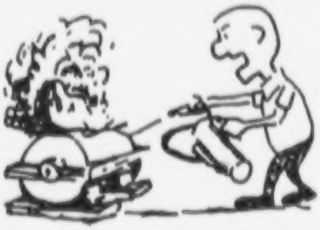


C. Pump tank — Place foot on foot pump and direct stream at base of fire; use on **class A** fires only.



INFORMATION SHEET

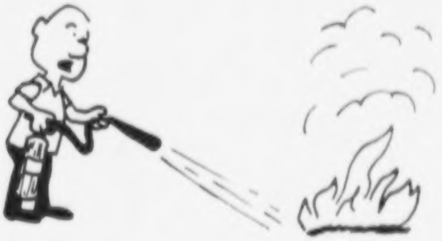
D. Dry chemical — Direct at the base of the flames and with a class A fire, follow up by directing the dry chemicals at remaining materials that is burning; use for class B or class C fires.



E. Halon — Stand back ten feet, hold upright, and direct at the base of fire, sweeping from side to side; use for class C fires.

(NOTE: Halon is a clean, liquified gas which does not leave a residue.)

(CAUTION: High concentration of burnt halon gas may be hazardous to your health.)



VII. **Safety color coding**

A. Green

1. Applied to nonhazardous part of machine and equipment surfaces, like nameplates and bearing surfaces
2. Designates safe areas of equipment, and is also used to show location of safety equipment and first-aid materials

B. Yellow

1. Applied to operating levers, wheels, handles, and hazardous parts that may cause stumbling, falling, snagging, or tripping
2. Designates caution

INFORMATION SHEET

C. Orange

1. Applied to electrical switches, interior surfaces of doors, fuses and electrical power boxes, and movable guards and parts

2. Indicates dangerous parts of equipment which may cut, crush, shock, or otherwise physically injure someone

D. Red

1. Applied to buttons or levers of electrical switches used for stopping machinery, and to all equipment, such as gasoline cans, which are fire hazards

2. Designates fire hazards and fire-fighting equipment

(NOTE: The color red is also applied to other fire-fighting equipment, such as fire alarms, fire axes, and emergency exits.)

E. Blue

1. Used to identify equipment which is being repaired or is defective and should not be operated

2. Designates "out of order" or "defective"

F. Ivory

1. Applied to table edges, vise jaws, and edges of tool rests where extra light reflection is important

2. No particular designation except to help show tool and equipment moving edges more clearly

VIII. General safety rules

A. Keep all hand tools clean and in safe working order.

B. Report any defective tools, test equipment, or other equipment to the instructor.

C. Do not remove any safety devices, (i.e. ground straps, switch covers, etc.) without the permission of the instructor.

D. Do not operate or energize any circuit that could be hazardous without first receiving instruction on how to do so safely.

E. Report all accidents to the instructor regardless of nature or severity.

INFORMATION SHEET

F. Turn off power before leaving test equipment or circuits being worked on.

G. Do not use any solvent without first determining its properties, and how to use it safely.

(NOTE: Solvents should be used only in well-ventilated spaces.)

H. Keep the laboratory floor clean of scraps and litter.

I. Clean up any spilled liquids immediately.

J. Isolate line (power) voltages from ground by means of isolation transformers.

K. Check all line (power) cords before using and if the insulation is brittle and/or cracked, DO NOT USE and report to the instructor.

L. When measuring voltages with a meter and test probe, be careful not to connect yourself to a voltage of any value.

M. Be certain that floor is insulated either by tile, rubber mats, or the wearing of rubber-soled shoes.

N. When measuring voltages expected to be greater than 30 volts, turn off or disconnect live circuit before connecting test equipment, or follow manufacturer's recommended procedures.

(NOTE: Always treat voltages with great respect.)

O. It is recommended that only equipment with a polarized (3-prong) plug be used.

P. Do not defeat the purpose of any safety device such as fuses, circuit breakers, or interlocks; shorting across these devices could cause excessive current flow, and destroy or seriously damage equipment being worked on, as well as cause a fire.

Q. Do not carry sharp-edged or pointed tools in your pockets.

R. Do not indulge in horseplay or play practical jokes in any work area.

S. Wear safety glasses when required.

T. Do not wear rings or jewelry when working with electrical devices.

U. Wear proper clothing.

V. Exericise good judgment and common sense.

INFORMATION SHEET

IX. **Types of hand tools and equipment** (Transparencies 2, 3, 4, 5, 6, 7 and 8)

A. Pliers

1. Long nose chain pliers

   (NOTE: These are commonly called needlenose pliers.)

2. Diagonal cutting pliers

3. Lineman's side cutting pliers

4. Combination slip joint pliers

B. Saws

1. Hacksaw

2. Hole saw

C. Screwdrivers

1. Flat blade (slot-head) screwdriver

2. Phillips® head (cross-point) screwdriver

3. Torx® driver

   (NOTE: Torx driver is a b point fastening system with maximum torque, and minimum slippage. Due to its shape, it is often called a "star fastener.")

4. Pozidriv® driver

   (NOTE: Although the pozidriv® screwdriver resembles the Phillips® tip configuration, the two should never be interchanged.)

D. Adjustable wire strippers

E. Electrician's six-in-one tool

F. Wrenches

1. Adjustable wrench

2. Hex and spline wrench

G. Nut driver

INFORMATION SHEET

- H. Hemostat clamp
- I. Ball peen hammer
- J. Files
    - 1. Flat file
    - 2. Half-round file
    - 3. Precision file
- K. Punches
    - 1. Center punch
    - 2. Square hole punch
    - 3. Round hole punch
- L. Mechanical wire strippers
- M. Thermal wire strippers
- N. Soldering iron stand
- O. Heat sink
- P. Component lead cleaner
- Q. Solder sucker
- R. Shrink tubing
- S. Insertion or removal tool
- T. Drill and drill bits
- U. Wire gauge
- V. Soldering vise
- W. Crimping tool (open barrel)

X. Hand tools and equipment and their uses

- A. Long nose chain pliers
    - 1. Holding components
    - 2. Heat sink
    - 3. Shaping and forming small conductors

INFORMATION SHEET

B. Diagonal cutting pliers

1. Cutting wire and component leads
2. Stripping insulation from wire

C. Lineman's side cutting pliers

1. Cutting heavier conductors and cables
2. Cutting small screws
3. Stripping insulation from wires
4. Forming large conductors

D. Combination slip joint pliers

1. Loosening small to medium size nuts and bolts
2. Holding and turning

E. Screwdrivers — Removing or tightening screws and bolts (flat-blade, Phillips®, Torx®, or Pozidriv®)

F. Hacksaw

1. Cutting chassis metal
2. Cutting bolts or metal parts

   Example: Antenna installation parts, or screws and bolts too large to cut with side cutting pliers

G. Electrician's six-in-one tool

1. Crimping solderless connections
2. Cutting wire
3. Stripping insulation from wire
4. Shearing bolts
5. Thread gauges
6. Length gauges for stripping

H. Nut drivers

1. Holding nuts or bolt heads
2. Tightening or loosening nuts or bolts

INFORMATION SHEET

I. Hex and splint wrenches

   1. Tightening,or loosening socket cap screws

   2. Tightening or loosening set screws

J. Hole saws and hole punches

   1. Cutting holes up to four inches in diameter

   2. Punching round or square holes in metal

K. Mechanical wire strippers — For cutting and pulling insulation from ends of conductors

L. Thermal wire strippers — For removing wire insulation by heating and melting the material; prevents wire strands, but cannot be used on insulation that will not melt, such as glass braid or asbestos

M. Soldering iron stand — For supporting a hot soldering iron when not in use

N. Soldering vise — For clamping and holding a printed circuit board or other component during soldering or other repair operations

O. Crimping tool — For making a strong mechanical connection to certain sleeve-type terminals

P. Shrink tubing — For preventing electrical connections from becoming shorted to adjacent connections

Q. Heat sink — For drawing heat from soldered connection to prevent damage to components

R. Component lead cleaner — For removing oxides and other films from component leads

S. Insertion or removal tool — For inserting or removing integrated circuits without bending pins

XI. Factors to consider when selecting hand tools

(NOTE: When in doubt about what tools are best, consult a practicing electronics specialist in your area.)

A. Tool size should be matched to the work most frequently encountered.

B. Tools should be specifically designed for electronic use when possible.

   Examples: Insulation on handles of pliers and screwdrivers

INFORMATION SHEET

C. Know the specifications before purchasing a tool.

Example: Pliers, long chain nose, 5", with plastic grip handles, and serrated jaws

Flat blade screwdriver, electrician's round shank, 6" × 3/16" blade w/cushion grips

XII. **Tool maintenance procedures**

A. Screwdrivers

1. Regrind worn or damaged f[illegible] blade screwdrivers.

2. Discard damaged Phillips* screwdrivers.

B. Pliers

1. Keep pliers clean and rust free.

2. Keep cutting edges sharp and smooth.

3. Keep pliers working freely.

4. Repair or replace damaged handle insulation.

C. Adjustable wrenches — Keep worm gears clean and lubricated.

D. All tools — Identify tools by labeling with an electric vibrator pen or scratch awl.

XIII. **Types of soldering tools and their uses** (Transparency 9)

A. ISO-TIP, 10 to 36 watts — For soldering isolated electrical connections; eliminates electrical leakage and the need for grounding

B. Soldering pencil, 10 to 36 watts — For soldering small electrical connection

C. Soldering gun, 100 watts — For soldering large electrical connections when better heat control is required

D. Temperature controlled soldering unit — For soldering many connections in close space

XIV. **Solder and flux**

A. Solder — For making electrical connections; most common type is 60/40 rosin-core solder containing 60% tin and 40% lead, with a center core of rosin flux to allow simultaneous application of both solder and flux

1. Solder for electronic applications is available in bars, sheets, wire spools, and special forms such as pellets, rings, and washers.

INFORMATION SHEET

2. Wire solders in the range from 0.030" to 0.090" in diameter are commonly used for hand soldering.

    a. Larger sizes are used for general purpose work.

    b. Smaller sizes are used for delicate soldering applications such as pc boards and solder cup-type pins found on certain connectors.

B. Flux — A chemical agent used to remove the thin films of oxide present on the metal surfaces to be soldered; when applied to the joint, the flux attacks the oxides and suspends them in solution where they float to the surface during the soldering process; there are three major classifications:

1. Chlorides (organic salts) are the most active and highly corrosive fluxes; they absorb moisture from the atmosphere and react strongly with acid at room temperature.

2. Organic (acids and bases) fluxes are slightly less active than chlorides; they are used mainly for confined areas where fast soldering time is important and corrosion is not a problem.

3. Rosin is used almost exclusively for its noncorrosive characteristics at room temperature; is corrosive at the melting point of solder which cleans the area while heated (approximately 361°F).

XV. **Primary purposes for solder in electrical applications**

A. Makes connections with virtually no resistance to electrical current flow

Example: Components soldered to printed circuit boards

B. Prevents corrosion of conductors, connections, and parts

Example: Printed circuit runs are often entirely covered with solder; terminal lugs are often coated with solder

C. Makes connections mechanically stronger

Example: Soldered connections will not pull apart as easily as wires that are merely twisted together

D. Seals containers to keep out dust and moisture

Example: Radio frequency crystal cannisters are sealed with solder; small, encased transformers or relays may be sealed with solder

INFORMATION SHEET

XVI. Safe soldering procedures

(CAUTION: A hot iron can burn a finger or start a fire. Use care. Be sure the power cord is not where you can trip over it. Wear safety glasses when soldering.)

A. Select the soldering iron for a specific application.

(NOTE: The soldering iron must be grounded when working on electrostatic sensitive components.)

B. Prepare soldering tip prior to use by a process termed tinning.

C. Prepare area to be soldered.

  1. Remove surface contaminants and oxides.
  2. Apply liquid flux to area to be soldered.

D. Place small amount of solder on tip of iron to aid heat transfer.

E. Place tip of iron next to terminal area and lead.

F. Place solder on opposite side of the lead.

G. Remove solder from heat after it has flowed and formed a smooth contour of solder around the lead and terminal pad.

H. Remove soldering iron.

(NOTE: Unplug the iron when not in use.)

I. Allow soldered area to cool.

J. Remove contaminated flux residue from soldered area.

XVII. Types of connections

A. No mechanical connection prior to soldering (Transparency 10)

  1. Butt connections (no mechanical security)
    a. Wire-to-wire
    b. Flat-to-flat

  (NOTE: Butt connections are used rarely in electrical circuits.)

  2. Lap connections (no mechanical security)
    a. Wire-to-wire
    b. Wire-to-flat

INFORMATION SHEET

        c. Flat-to-flat

        d. Wire-to-post

        e. Wire-to-cup or sleeve

        f. Wire-to-hole

B. Partial mechanical connection prior to soldering (Transparency 11)

    1. Wire-to-hook

    2. Wire-to-flat lug

    3. Wire-to-turret or post

C. Full mechanical connection prior to soldering (Transparency 11)

    1. Wire spliced to wire

    2. Wire to flat lug

    3. Wire to turret or post

    4. Wire to crimp sleeve

XVIII. **Types of desoldering tools and their processes** (Transparency 12)

A. Solder wick

    1. Used to remove excess solder from the connection

       (NOTE: The solder wick is made of finely woven strands of copper wire.)

    2. Process

        a. Place wick over terminal area and lead to be desoldered.

        b. Place solder iron tip in contact with the solder wick and press down against the connection.

        c. The solder will melt and flow in the direction of the heat transfer. The solder is trapped by the solder wick as it flows up through the weave.

        d. With the solder removed from the connection, the lead can be bent away from the terminal pad and the component removed.

INFORMATION SHEET

B. Desoldering bulb

1. Used for removing excess solder or for desoldering component leads
2. Process
    a. Apply heat to area to be desoldered
    b. As solder begins to melt the bulb pressure is released
    c. The liquid solder is drawn up into the bulb by the suction
    d. If solder remains, the process must be repeated

C. Solder sucker

1. Used in the same manner as the desoldering bulb except that the suction is produced by a spring loaded piston

    (CAUTION: When working with MOS integrated circuits, it is necessary to use an anti-static solder sucker to eliminate static electricity.)

2. Process
    a. Push the piston handle downward
    b. Rotate the handle to engage the release pin
    c. As the solder begins to melt, the pin is disengaged
    d. The solder is drawn up through the hollow tip as the spring pushes the plunger upward

(NOTE: Both the desoldering bulb and the solder-sucker are easily disassembled to remove the accumulated solder. It may be necessary to use an anti-static solder sucker to eliminate static electricity.)

XIX. Cleaners and lubricants

(NOTE: Many of the cleaners and lubricants listed below may be hazardous to your health. Read labels carefully and clean hands thoroughly after use.)

Cleaners	*Type*	*Application*
Alcohol, ethyl	Petroleum solvent	Cleaning solder connections Thinner for shellac and rosin
Acetone	Petroleum solvent	Removal of oily films, paints, and lacquer Lucite cement
Bright dip	Acid mixture containing sulfuric, hydrochloric, and nitric acids	Cleaning metal surfaces after etching or soldering

INFORMATION SHEET

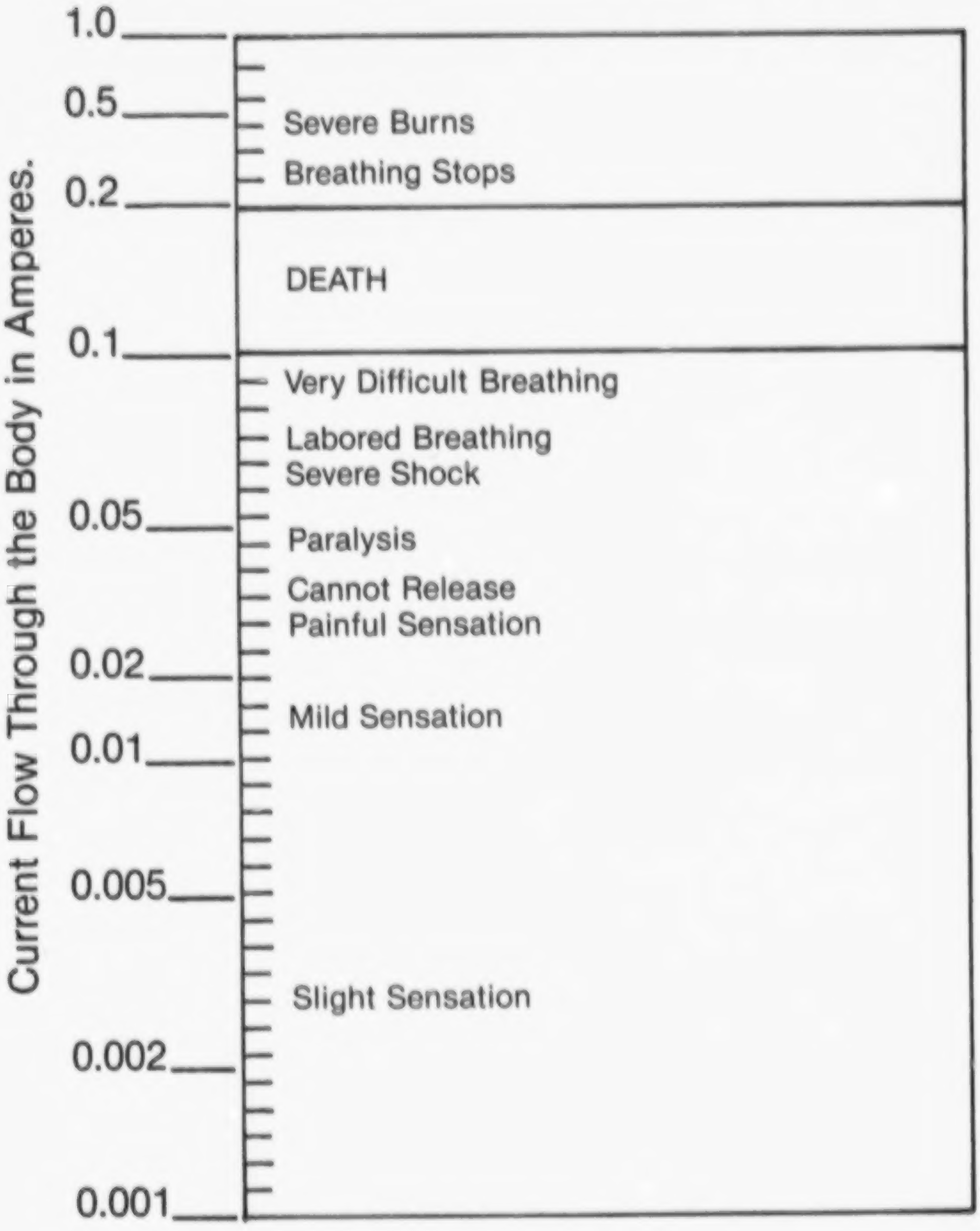
Cleaners	*Type*	*Application*
Butyl cellulose	Petroleum solvent	Thinner and wash-up for epoxy resin inks
Cyclohexanone	Petroleum solvent	Vinyl solvent and cement thinner
Hydrochloric acid	Diluted acid	Remove mill scale from steel Bright dip ingredient
Isophorone	Petroleum solvent	Wash-up for vinyl inks
Isopropyl alcohol	Petroleum solvent	For removing oil, grease, and flux from conductors and terminals both before and after soldering
Kerosene	Petroleum solvent	Machine cutting fluid
Ketone, methyl ethyl	Petroleum solvent	Lacquer thinner and paint remover
Lacquer thinner	Petroleum solvent	Thinner and wash-up for lacquer and lacquer ink
Mineral spirits	Petroleum solvent	Wash-up and thinner for rubber, oil, ethyl cellulose inks, and alkyd enamels
Perchlorethylene	Chlorinated solvent	General-purpose cleaner and vapor degreaser
Phosphoric acid	Diluted acid	Remove milk scale from steel
Sodium hydroxide	Alkaline solvent	Cleaning and etching aluminum
Toluene	Petroleum solvent	Wash-up and thinner for rubber, oil, ethyl cellulose inks, and alkyd enamels
Trichloroethane	Chlorinated solvent	Wash-up layout dye and screen inks Ultrasonic cleaning

INFORMATION SHEET

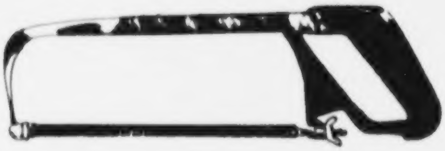
Cleaners	*Type*	*Application*
Trichlorethylene	Chlorinated solvent	General-purpose cleaner and vapor degreaser
Turpentine	Petroleum solvent	Machine cutting fluid
Xylene	Petroleum solvent	Thinner for acrylic printing inks Wash-up for synthetic enamels and photo resist ink

Lubricant	*Application*
WD40	*General purpose lubricant*
3-in-1 oil	*General purpose lubricant*

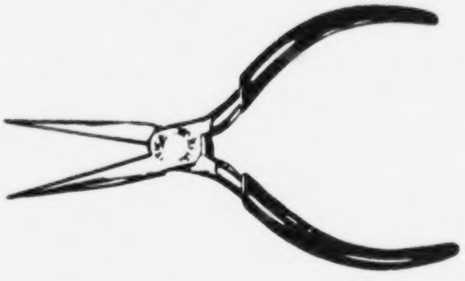
Electric Shock Versus Body Sensation



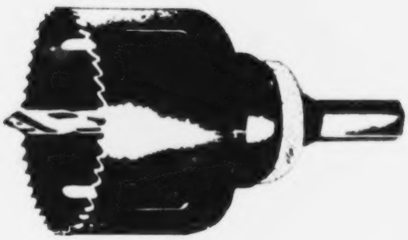
Hand Tools



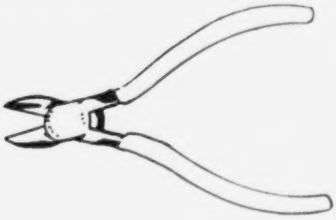
Hacksaw



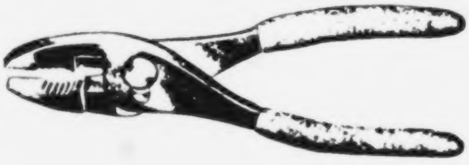
Long Nose Chain Pliers



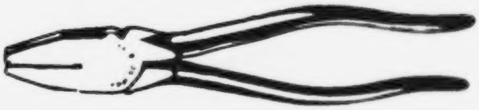
Hole Saw



Diagonal Cutting Pliers



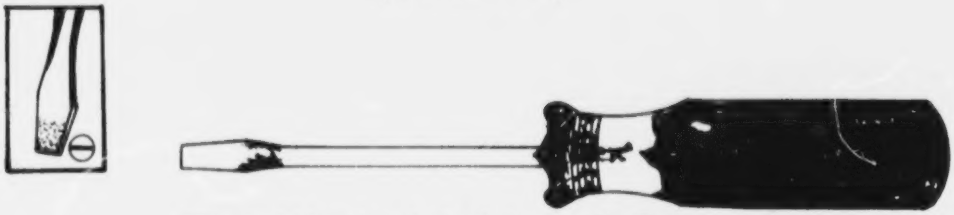
Combination Slip-Joint Pliers



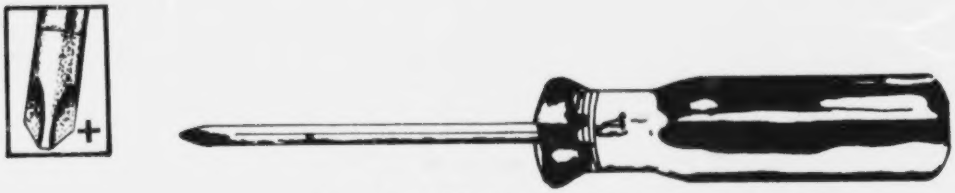
Lineman's Side Cutting Pliers

Hand Tools

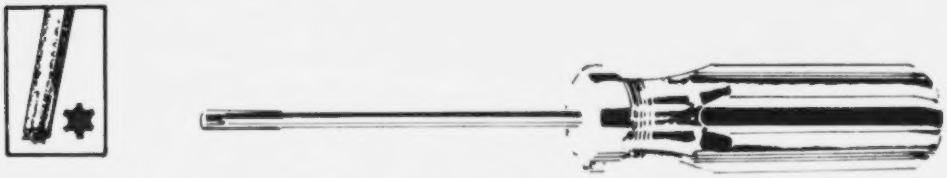
(Continued)



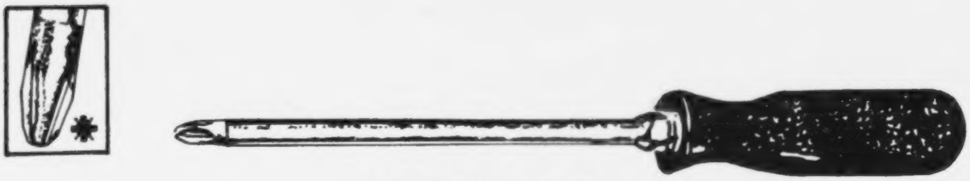
Flat Blade (slot-head) Screwdriver



Phillips® Head Screwdriver



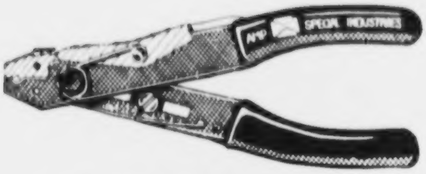
Torx® Drivers



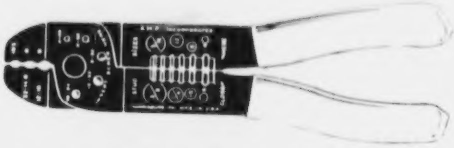
Pozidriv® Drivers

Hand Tools

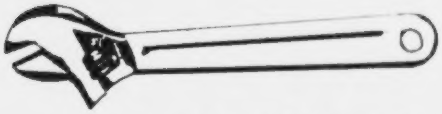
(Continued)



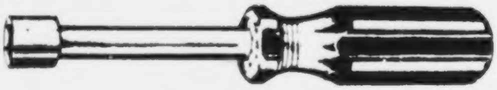
Adjustable Wire Strippers



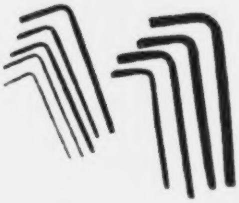
Electrician's Six-in-One Tool



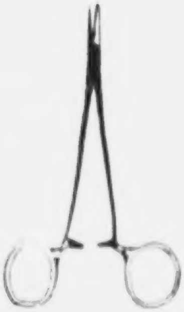
Adjustable Wrench



Nut Driver



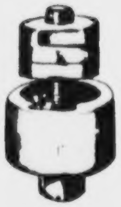
Hex and Spline Wrenches



Hemostat Clamp

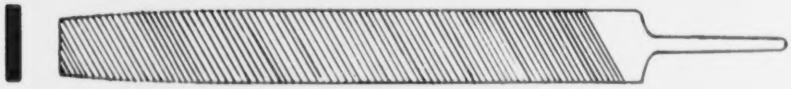
Hand Tools

(Continued)

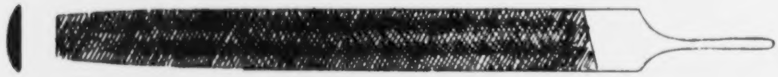


Round Hole Punch

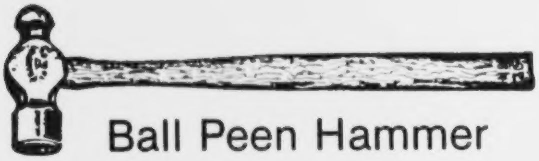
Center Punch



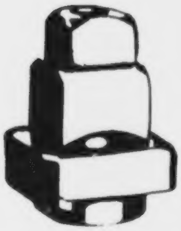
Flat File



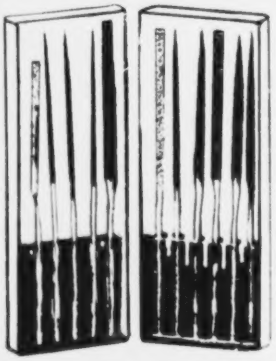
Half-Round File



Ball Peen Hammer



Square Hole Punch

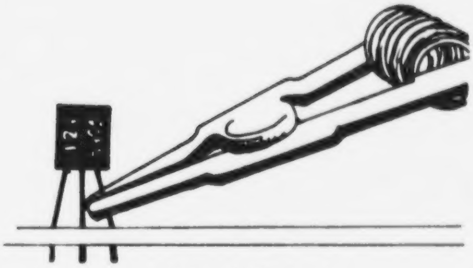


Precision Files

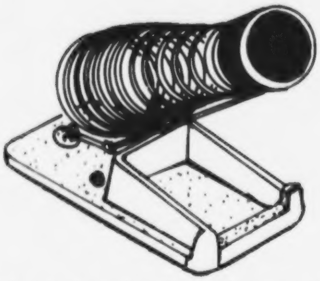
Hand Tools

(Continued)

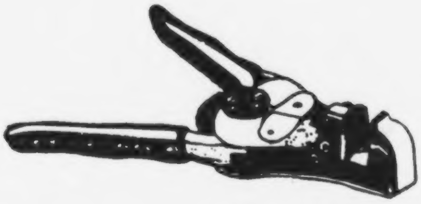
Solder Sucker



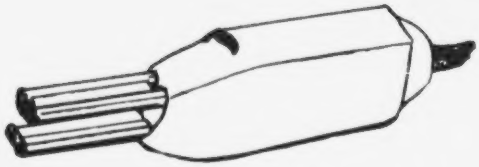
Heat Sink



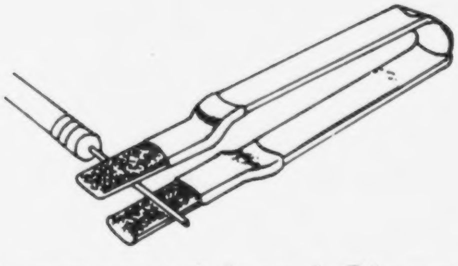
Soldering Stands



Mechanical Wire Strippers



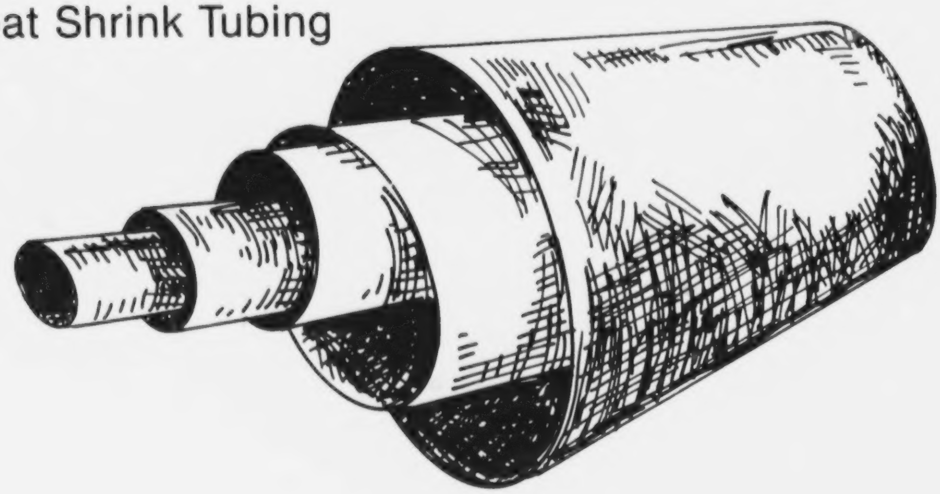
Thermal Wire Stripper



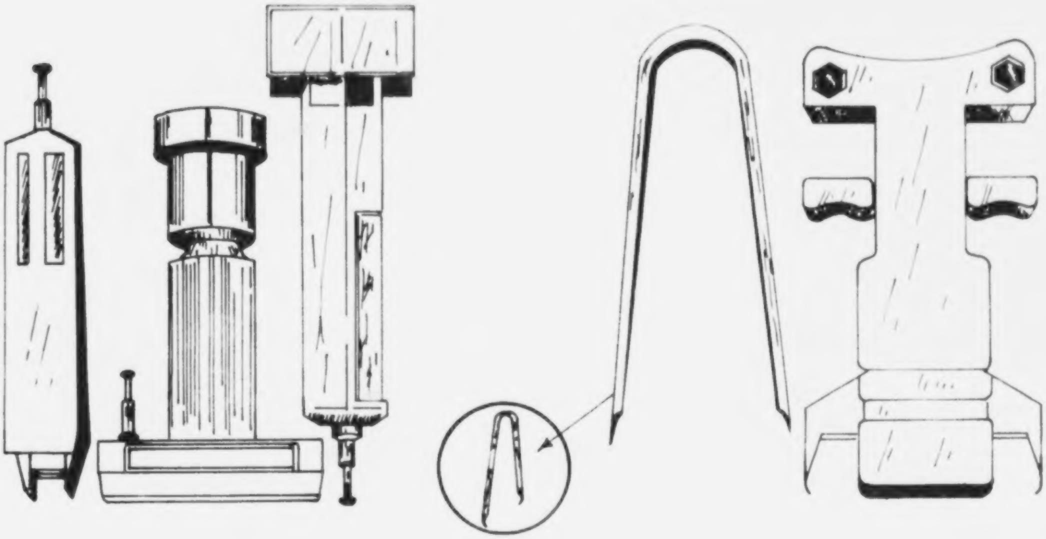
Component Lead Cleaner

Hand Tools

(Continued)



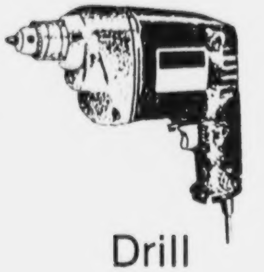
Heat Shrink Tubing



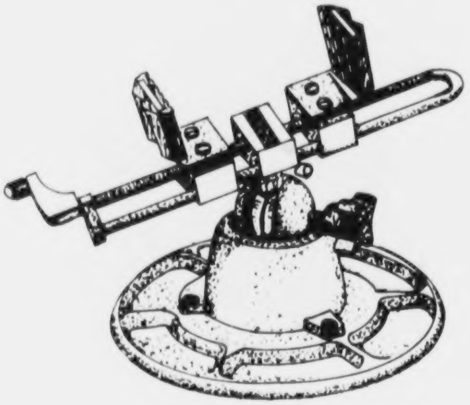
Insertion and Extraction Tools

Hand Tools

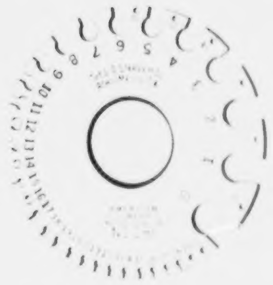
(Continued)



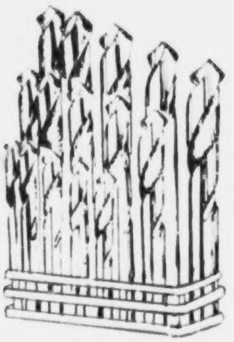
Drill



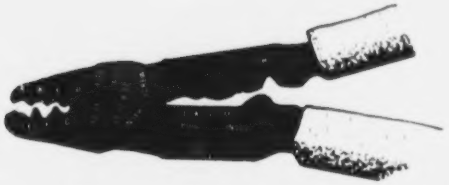
Soldering Vise



Wire Gauge

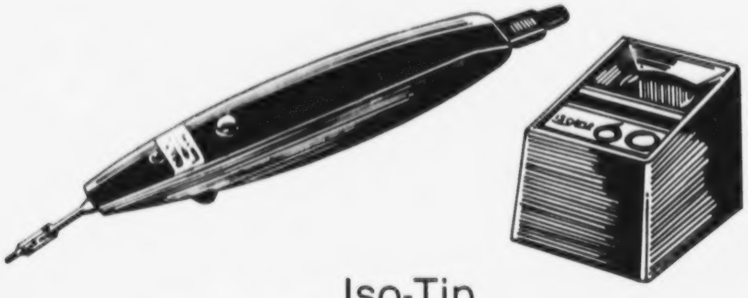


Drill Bits

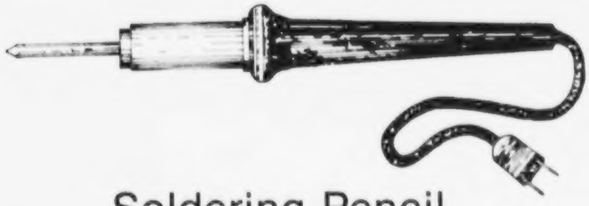


Open Barrel Type Crimp Tools

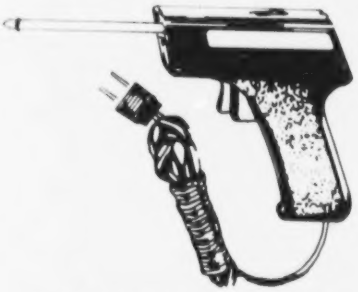
Types of Soldering Tools



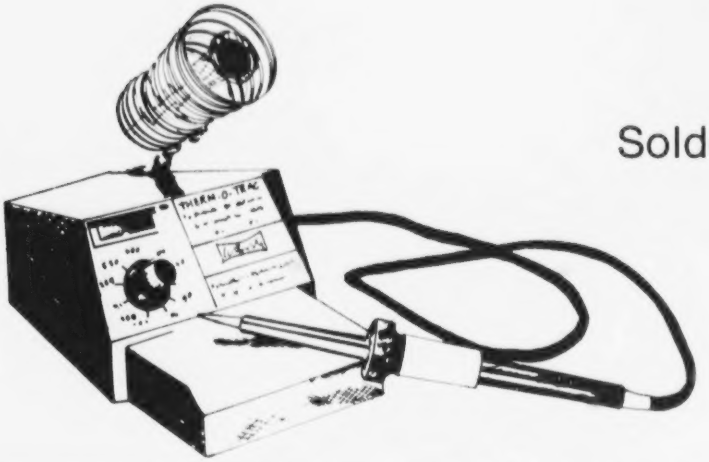
Iso-Tip



Soldering Pencil



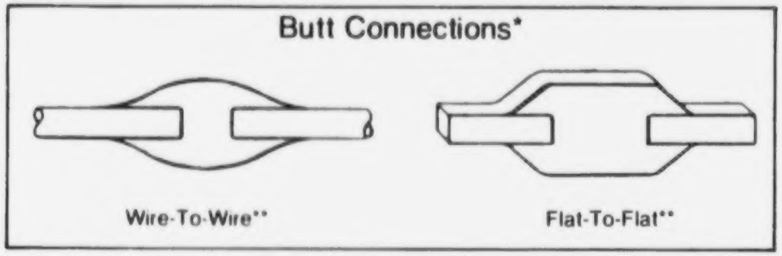
Soldering Gun

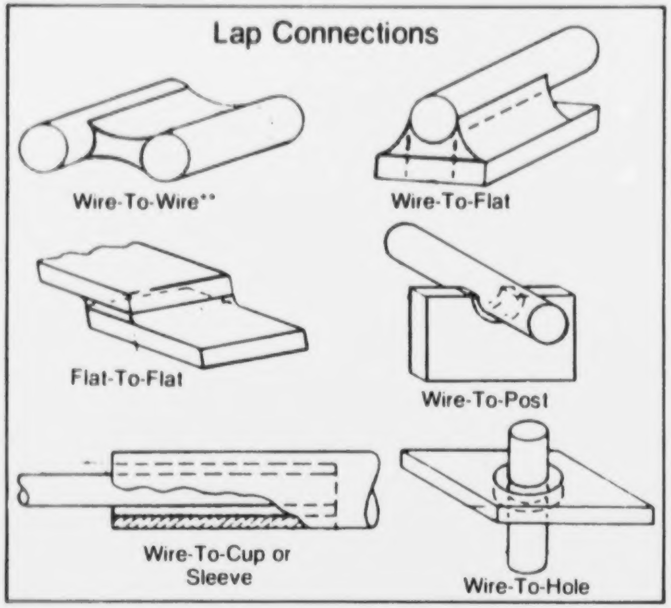


Temperature Controlled Soldering Unit

Soldered Connections

No Mechanical Security Prior to Soldering


Butt Connections*
Wire-To-Wire**
Flat-To-Flat**

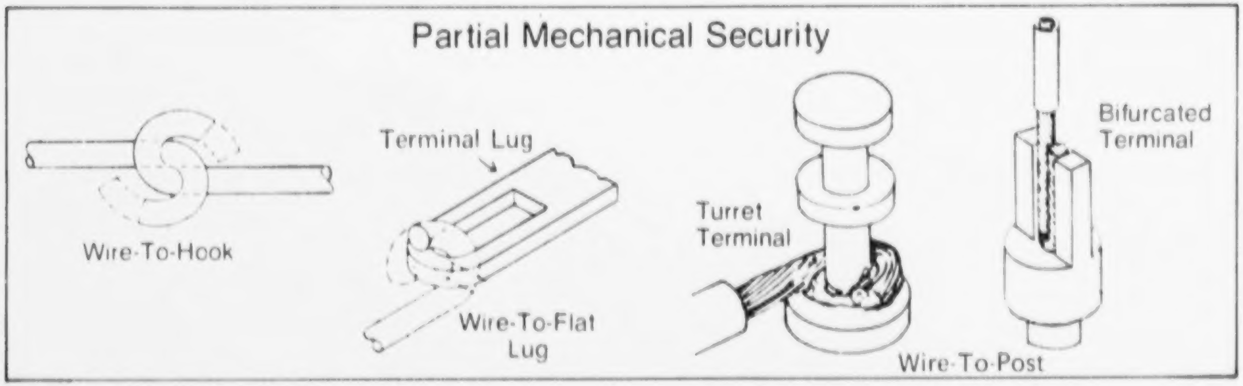

Lap Connections
Wire-To-Wire**
Wire-To-Flat
Flat-To-Flat
Wire-To-Post
Wire-To-Cup or Sleeve
Wire-To-Hole

*Butt Connections are Seldom Used in Electrical Work

**These Connections Require a Fixture to Prevent Movement During Soldering

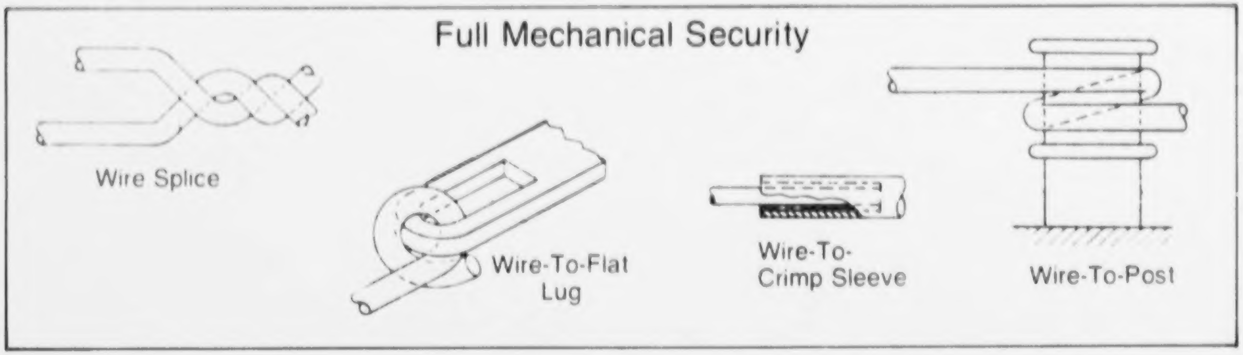
Soldered Connections

With Mechanical Security Prior to Soldering



Partial Mechanical Security

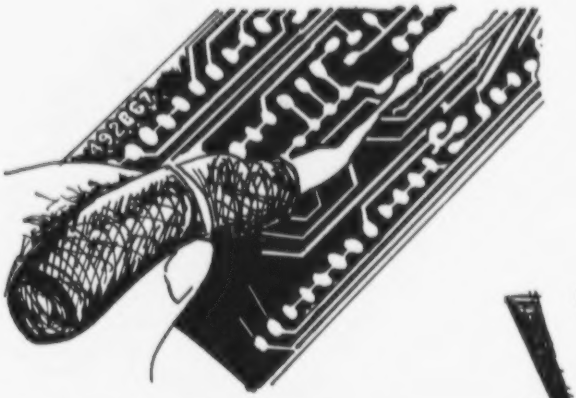
Wire-To-Hook
Terminal Lug
Wire-To-Flat Lug
Turret Terminal
Bifurcated Terminal
Wire-To-Post



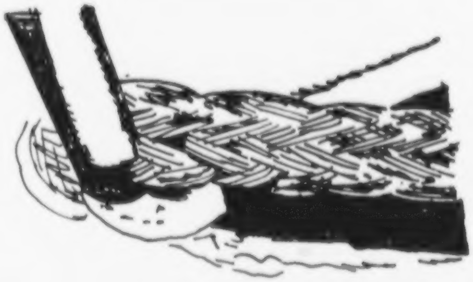
Full Mechanical Security

Wire Splice
Wire-To-Flat Lug
Wire-To-Crimp Sleeve
Wire-To-Post

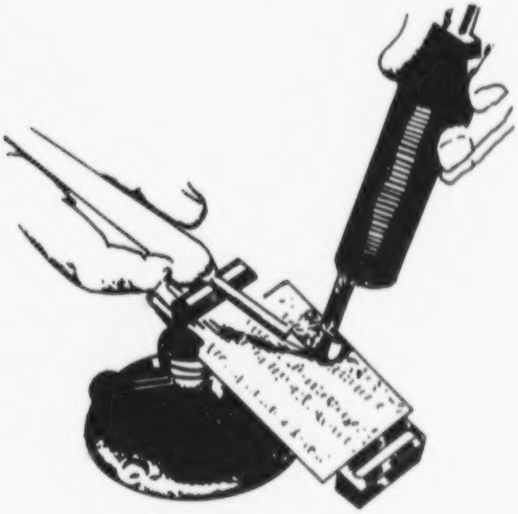
Types of Desoldering Tools



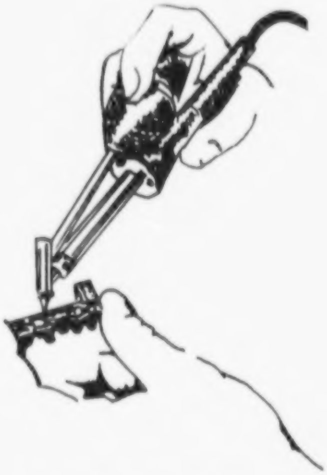
Desoldering Bulb



Solder Wick



Solder Sucker



Desoldering Iron Attachment

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

JOB SHEET #1 — PREPARE A SOLDERING IRON TIP FOR USE

A. Equipment and materials needed

1. Soldering iron — Pencil iron with copper or iron-clad tip
2. Damp sponge
3. Fine wire brush
4. Fine metal file
5. Tip cleaning flux if available (not necessary)
6. Tinning oil if available (not necessary)
7. 60/40 solder
8. Soldering iron holder
9. Safety glasses

B. Procedure

1. Put on safety glasses.
2. While the soldering iron is cool, and before connecting it to the power receptacle, inspect the tip.

   (NOTE: Copper tips can be reshaped with a metal file.)

3. File the tip to a wedge shape without removing any more metal than is necessary.

   (NOTE: Iron-clad tips should not need reshaping. If you have an iron-clad tip that is in poor shape, ask your instructor if it should be filed or replaced. Normally iron-clad tips are merely cleaned with a wire brush. Filing will shorten their useful life. Gold plated tips are used for particular applications and are expensive. Gold plated tips should never be filed or brushed. Cleaning is usually accomplished with a damp sponge once the tip is hot. Special cleaning fluxes are used by industry for production line tips. However, if the shank of the tip is carboned or corroded, it can be brushed with the wire brush.)

4. Place soldering iron in holder, and connect power cord to receptacle.

JOB SHEET #1

5. Apply tinning oil, if available, to the hot tip.

   (NOTE: Do not put the tip into the oil container. Remove a small amount of tinning oil with a clean applicator or the tip of a clean screwdriver. Allow a drop to flow onto each surface of the hot tip's wedge.)

6. Apply 60/40 solder to the tip's wedged surfaces.

   (CAUTION: Hot solder may drip from the tip. Allow it to drip onto the wet sponge. It can burn your skin or damage clothing.)

7. Wipe excess solder from the tip onto the wet sponge.

8. Disconnect the soldering iron from the receptacle, and place it in the holder to cool.

   (NOTE: After the iron has cooled, show it to your instructor.)

9. Return equipment and materials to their proper storage area.

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

JOB SHEET #2 — ADJUST WIRE STRIPPERS

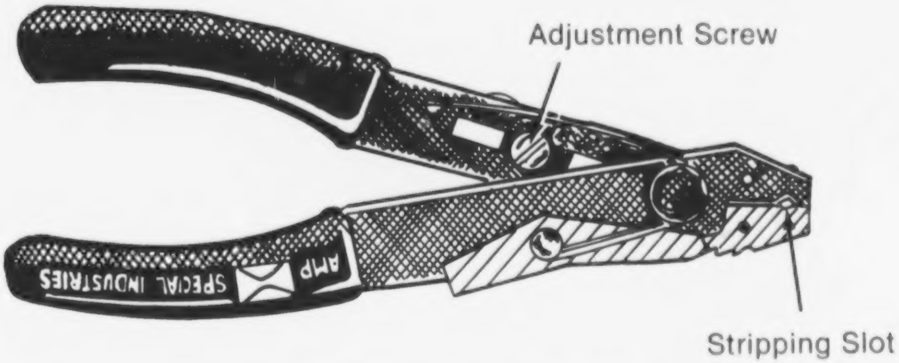
A. Equipment and materials needed

1. Adjustable wire strippers
2. Variety of solid and stranded insulated conductors
3. Screwdriver or nut driver to fit adjustment screw

B. Procedure

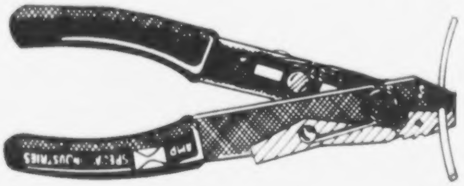
1. Loosen adjustment screw. (Figure 1)

FIGURE 1


Adjustment Screw
AMP
SPECIAL INDUSTRIES
Stripping Slot

2. Insert conductor into stripping slot.
3. Close jaws until you feel that you have reached the conductor.
4. Open jaws slightly.
5. Slide adjustment screw down to its resting position. (Figure 2)

FIGURE 2


AMP
SPECIAL INDUSTRIES

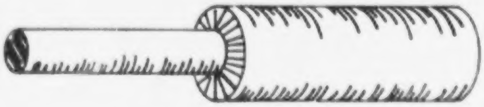
JOB SHEET #2

6. Strip off approximately 3/8-inch of insulation.

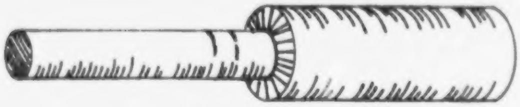
7. Check conductor for ring or nick. (Figure 3)

(NOTE: If nick occurs, loosen adjustment screw, readjust, and test again until insulation is removed without conductor damage.)

FIGURE 3



Correctly Adjusted



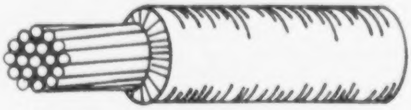
Incorrectly Adjusted

8. Strip off approximately 3/8 inch of insulation.

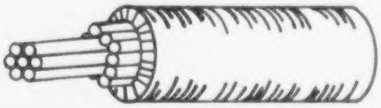
9. Check conductor for cut strands. (Figure 4)

(NOTE: Cutting of strands reduces the current carrying capability of the conductor. Loosen adjustment screw, readjust, and test again until insulation is removed without conductor damage.)

FIGURE 4



Correctly Adjusted



Incorrectly Adjusted

10. Return equipment and materials to their proper storage area.

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

JOB SHEET #3 — STRIP AND TIN WIRES FOR SOLDERED CONNECTIONS

A. Equipment and materials needed

1. Soldering iron (20-30w)
2. 60/40 rosin core solder (18 gauge)
3. Soldering iron holder
4. Mechanical wire strippers
5. Two six-inch lengths of 22-gauge stranded wire
6. Acid brush
7. Wire stripper
8. Damp sponge
9. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Plug soldering iron into AC outlet.
3. As soon as the tip is hot, tin the iron tip; remove excess solder with a damp sponge.
4. Using mechanical wire strippers, strip about one inch of insulation from each end of each wire length.
5. Clean stripped wire ends with isopropyl alcohol and clean cloth.
6. Gently twist wire ends in direction of strand twist so that strands do not separate.
7. Place wire end on heated iron tip and apply solder until solder freely flows among all wire strands; remove wire and solder.
8. Clean tinned wire using isopropyl alcohol and acid brush.

JOB SHEET #3

9. Check that excessive solder has not been applied (outline of all strands should be visible through the solder) and that wire insulation shows no evidence of burning or wicking.
10. Repeat tinning operation.
11. Have your instructor check your work.
12. Return equipment and materials to their proper storage area.

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

JOB SHEET #4 — SOLDER WIRES TO TURRET TERMINALS, THEN DESOLDER WIRES

A. Equipment and materials needed

1. Soldering iron, with stand
2. Soldering vise, for holding the terminal board during soldering
3. Safety glasses or goggles
4. Wire strippers
5. Long nose or needle nose pliers
6. Rosin-core solder
7. Isopropyl alcohol
8. Acid brush
9. Bakelite® board with two turret terminals mounted on it approximately four inches apart
10. Two 6-inch lengths of 22-gauge stranded wire, stripped and tinned in accordance with Job Sheet #3

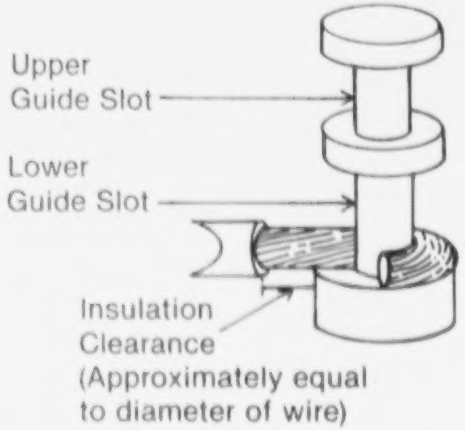
B. Procedure

1. Put on safety glasses.
2. Secure Bakelite® board in vise so that terminals are accessible for soldering.
3. Plug in soldering iron.
4. Properly strip ends of wire.
5. Properly tin wire.

JOB SHEET #4

6. Using pliers, form end of one wire around lower guide slot of one turret terminal. (Figure 1)

FIGURE 1


Upper Guide Slot
Lower Guide Slot
Insulation Clearance (Approximately equal to diameter of wire)

(NOTE: Figure 1 shows the wire wrapped 180° around the turret terminal. If desired, the wire may be wrapped 360° around the terminal to make a more secure mechanical connection prior to soldering. However, this may require stripping and tinning a longer length of the wire end.)

7. Using soldering iron and rosin-core solder, solder wire to terminal.

8. Clean soldered connection with isopropyl alcohol and clean cloth or acid brush.

9. Check that soldered connection is correct.

10. Solder opposite end of wire to lower guide slot of second terminal in same manner (Steps 4 through 9).

11. Solder second length of wire to upper guide slots of terminals in same manner (Steps 4 through 9).

12. Desolder all connections as follows:
    a. Apply hot iron tip to terminal to melt solder, and pry wire off terminal.
    b. While still applying hot iron tip, remove solder with a brush or solder sucker.
    c. Clean desoldered terminal with isopropyl alcohol and clean cloth.

13. Return equipment and materials to their proper storage area.

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

JOB SHEET #5 — SPLICE WIRES TOGETHER BY MEANS OF SOLDERING AND CRIMPING

A. Equipment and materials needed

1. Soldering iron (20-30 watts)
2. Crimping tool
3. 18 inches of #26 stranded wire
4. 24 inches of #20 wire
5. One splice lug for #20 wire
6. Two inches of shrink tubing for #26 wire
7. Heat gun
8. Electrical tape
9. Safety glasses
10. 60/40 rosin-core solder (22-gauge)

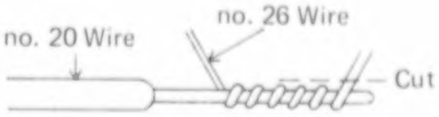
B. Procedure

1. Put on safety glasses.
2. Cut the #26 wire into three equal lengths.
3. Strip, clean, and tin one end of each length.
4. Cut the #20 wire into four equal lengths.
5. Strip, clean, and tin one end of each length.
6. Trim tinned ends of all wires to 1/2 inch length.

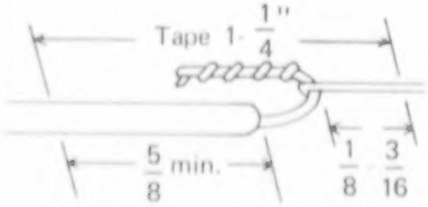
JOB SHEET #5

7. Splice tinned ends of one #20 wire and one #26 wire (Figure 1).

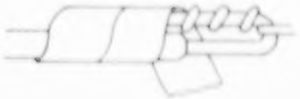
FIGURE 1


no. 20 Wire
no. 26 Wire
Cut

a. Wrap smaller wire around larger wire.


Tape 1-1/4"
5/8 min.
1/8 - 3/16

b. Bend wires back and solder full length of twist.

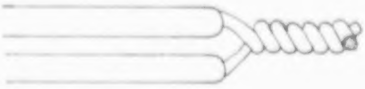


c. Apply electrical tape over splice.

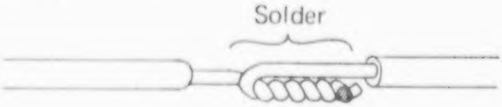
8. Install shrink tubing on one length of #26 wire.

9. Splice tinned ends of two lengths of #26 wire (including the one with the tubing). (Figure 2)

FIGURE 2

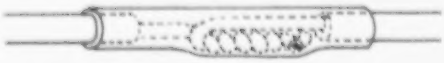


a. Twist wires together



b. Solder twisted ends

JOB SHEET #5



c. Slide heat shrink tubing over splice

10. Shrink the tubing by applying heat across the length of the tubing, WITHOUT TOUCHING THE TUBING.

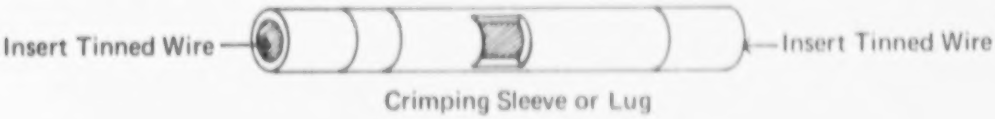
11. Continue applying heat until tubing fits snugly over the splice.

12. Insert tinned ends of two lengths of #20 wire in opposite ends of crimping lug (Figure 3); make sure strands of both wires are visible in slot at center of lug.

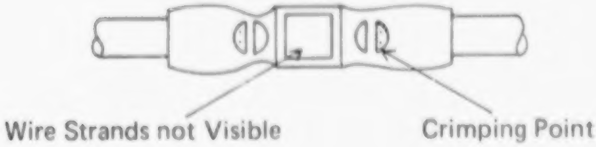
13. Using crimping tool, crimp both ends of lug.

14. Check that crimp is correct (Figure 3).

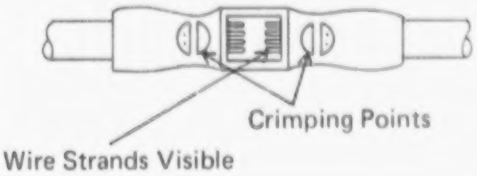
FIGURE 3


Insert Tinned Wire
Insert Tinned Wire
Crimping Sleeve or Lug

Incorrect Crimp


Wire Strands not Visible
Crimping Point

Correct Crimp


Crimping Points
Wire Strands Visible

15. Return equipment and materials to their proper storage area.

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

JOB SHEET #6 — REPAIR A PRINTED CIRCUIT BOARD

A. Equipment and materials needed

1. Vise or clamp
2. Soldering iron (20-30 watts)
3. Solder wick
4. Safety glasses
5. Isopropyl alcohol
6. 60/40 rosin-core solder (22-gauge)
7. Typewriter eraser
8. Acid brush
9. Chain nose pliers
10. Component lead cleaner
11. Printed circuit board with two damaged resistors, and open conducting path, and a broken or removed land
12. Two replacement resistors

B. Procedure

1. Put on safety glasses.
2. Plug in soldering iron and allow to heat.
3. Turn board so that the component side is down.
4. Place solder wick next to component lead to be removed.
5. Place soldering iron against the solder wick.

   (NOTE: When solder begins to melt, it will flow into the wire of the solder wick.)
6. Once all solder is removed from component lead and pad, remove the soldering iron and solder wick.
7. Repeat Steps 3-6 for other end of the component.

JOB SHEET #6

8. With solder removed from the component lead and pad the leads can be twisted away from the pad and the component removed.

9. Remove grease and rosin from connections by means of isopropyl alcohol and acid brushes.

10. Remove oxides from the land by means of the typewriter eraser.

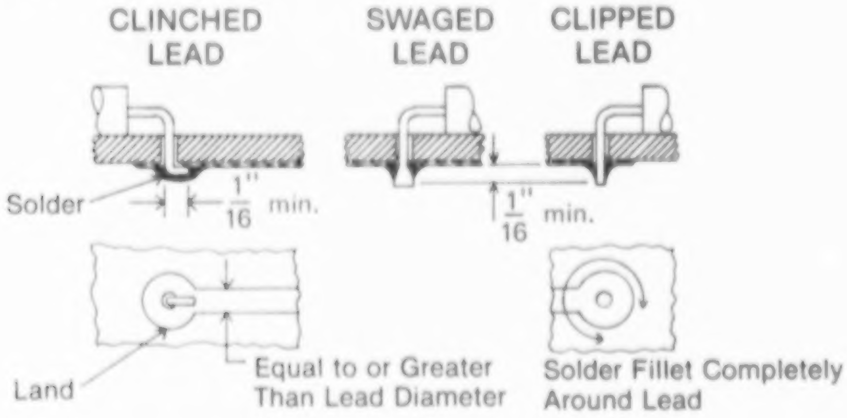
11. Clean oxides from replacement component leads by means of component lead cleaner.

12. Measure distance between component land connections and bend component leads at right angles so that the leads will insert into the land eyelets.

13. Insert component leads into land holes so that component lies on upper surface of board.

14. While holding component in place, turn board over and either clinch, swage, or clip component leads (Figure 1).

FIGURE 1


CLINCHED LEAD
SWAGED LEAD
CLIPPED LEAD
Solder
1"/16 min.
1"/16 min.
Land
Equal to or Greater Than Lead Diameter
Solder Fillet Completely Around Lead

(NOTE: Clinching provides the best mechanical connection. The leads are swaged or clipped when space limitations prevent clinching. If the leads are to be clipped, it may be best to postpone the clipping operation until after the connections have been soldered.)

15. Install boards in clamp or vise.

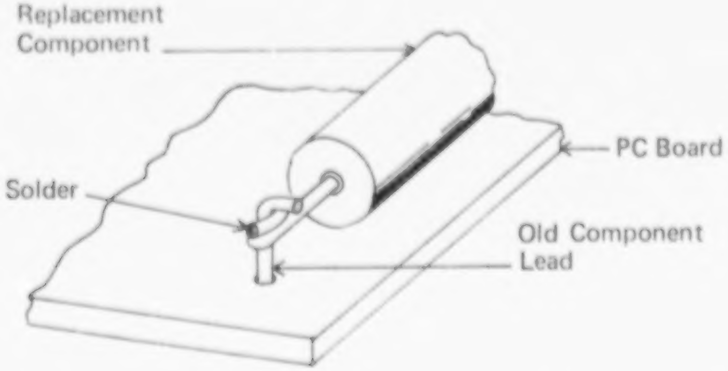
16. Attach heat sink to component lead at each end of component.

17. Solder component lead to land at each connection. (Figure 1)

JOB SHEET #6

18. Replace second resistor by cutting off damaged resistor and solder new resistor to old component leads. (Figure 2)

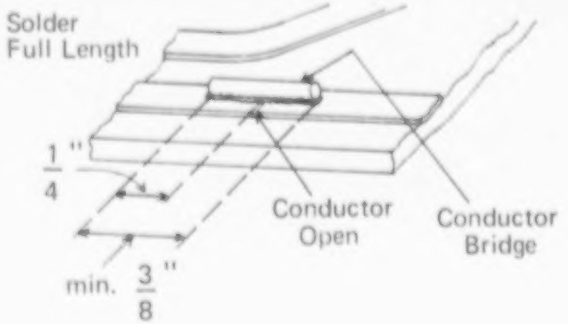
FIGURE 2


Replacement Component
PC Board
Solder
Old Component Lead

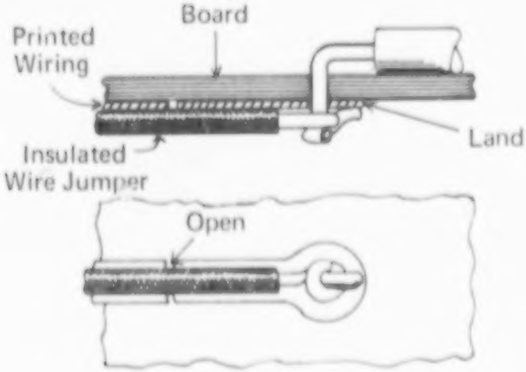
19. Repair open in printed wiring by soldering a conductor bridge across the open using one of the techniques. (Figure 3)

FIGURE 3

Solder Conductor Bridge Across Open as Shown


Solder Full Length
1/4"
Conductor Open
Conductor Bridge
min. 3/8"

...or...

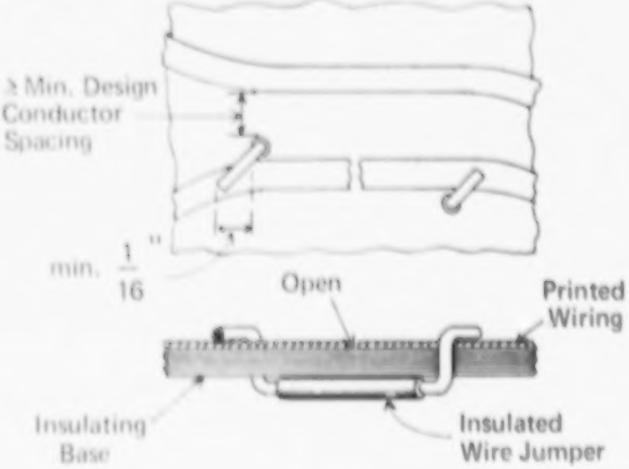

Board
Printed Wiring
Land
Insulated Wire Jumper
Open

Solder Insulated Wire Jumper Across Open on Conductor Side of Board

...or...

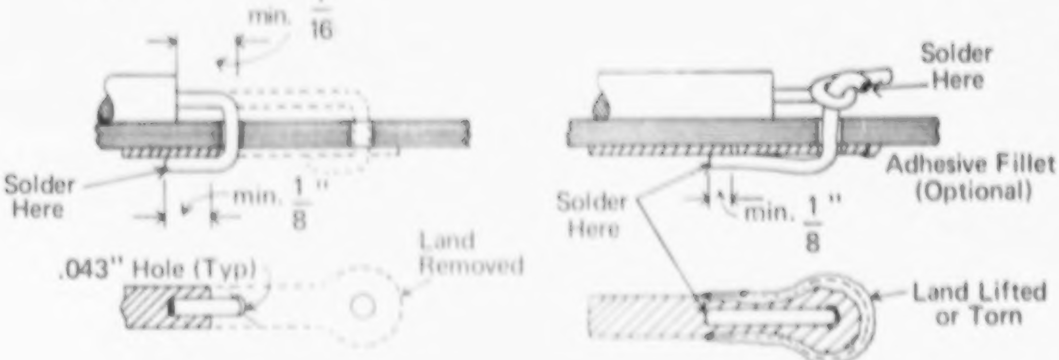
JOB SHEET #6

Solder Insulated Wire Jumper Across Open on Component Side of the Board


≥ Min. Design Conductor Spacing
min. 1/16 "
Open
Printed Wiring
Insulating Base
Insulated Wire Jumper

20. Repair removed or lifted land. (Figure 4)

FIGURE · 4


min. 1/16 "
Solder Here
min. 1/8 "
.043" Hole (Typ)
Land Removed
Solder Here
Adhesive Fillet (Optional)
Solder Here
min. 1/8 "
Land Lifted or Torn

21. Check all soldered connections for proper configuration.

22. Check that no solder has been spilled to cause possible shorts with adjacent connections or wiring.

23. Clean all soldered connections with isopropyl alcohol and acid brush.

24. Return equipment and materials to their proper storage area.

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

NAME ______________________

TEST

1. Match the terms on the right with their correct definitions.

(NOTE: Answers to questions a. through m. appear on this page.)

_____a. Solution that cleans metals before or during soldering, or chemically acts to aid the fusion process

_____b. Plastic, fiberglass, or phenolic board upon which copper strips interconnect between mounted components

_____c. Junction of two or more metals fused with solder

_____d. Having a curved form which bulges inward

_____e. Any unplanned event, occurring suddenly, which causes personal injury or damage to property

_____f. Solder-welding two edges at right angles

_____g. Having a curved form which bulges outward

_____h. Strip of conductor on a printed circuit board

_____i. Surface on which zinc has been deposited by the process of hot dipping or electroplating

_____j. A material obtained from pine trees which is used during soldering to help ensure a good bond between the solder and the metal surfaces

_____k. Films and impurities which form on the surface of metals when exposed to air or water and which, if not cleared off, will prevent a good bond between the surfaces and solder

_____l. Printed wiring attached to the surface of a printed circuit board

_____m. Round terminal connection point on a printed circuit board where component lead wires are attached

1. Rosin
2. Accident
3. Galvanized
4. Fillet
5. Oxides
6. Land
7. Solder joint
8. Printed circuit board
9. Run
10. Concave
11. Pad
12. Convex
13. Flux

TEST

(NOTE: Answers to questions n. through w. appear on this page.)

______n. The state of being free from danger, personal risk, or injury

______o. Applying mechanical pressure to compress a sleeve-type or cuptype electrical terminal to ensure a good electrical connection between the sleeve and the conducting wires it contains

______p. Flow of solder under the insulation of covered wire

______q. To unite (connect) two wires to form a continuous length

______r. Soft metal alloy of tin and lead used for plating or fusing metals together

______s. Plastic material (thermosetting resin) which becomes permanently hardened when subjected to heat; originally known as Bakelite©; used for printed circuit board construction

______t. Removing insulation from electrical conductors

______u. The ability of molten solder to flow over and fuse completely with the metal surfaces to which it is applied

______v. The application of a small amount of solder to surfaces to be soldered to help ensure good wetting during soldering

______w. Plastic insulating sleeve which shrinks in diameter with the application of heat to form a seal

14. Wicking
15. Crimping
16. Splice
17. Shrink tubing
18. Phenolic board
19. Tinning
20. Wetting
21. Solder
22. Stripping
23. Safety

2. List six hazards of working with electrical and electronic equipment.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

TEST

3. Complete the following list of statements concerning facts about electrical shock by inserting the word that best completes each statement.

   a. ____________ is usually considered more dangerous than ____________.

   b. High ____________ tends to knock the victim away from the circuit minimizing exposure time.

   c. High ____________ tends to cause the body to adhere to the circuit so that the victim cannot let go.

   d. At about ____________ milliamperes the shock is severe enough to paralyze muscles, but a person may be able to let go of the conductor.

4. Select true statements concerning treating a victim of electrical shock by placing an "X" in the blanks preceding the true statements.

   _____a. To safely remove the victim from contact with the source of electricity, turn off the electricity by means of a switch or circuit breaker or cut cables or wires by means of a wood handled axe or insulated cutters.

   _____b. Call for assistance as others in the area may be more knowledgeable than you about treating the victim.

   _____c. Check victim's temperature.

   _____d. Check victim's breathing and heartbeat; if heart has stopped administer cardiopulmonary resuscitation whether you have been trained in the proper technique or not.

   _____e. Use blankets or coats to help keep victim as warm and comfortable as possible while waiting for help.

   _____f. Raise victim's head slightly above body level to help prevent shock.

   _____g. If victim has suffered burns, wrap burned area firmly with sterile gauze or clean linen or towels.

TEST

5. Match types of fires on the right with their descriptions.

______a. Fires that occur in ordinary combustible materials

______b. Fires that occur in flammable liquids

______c. Fires that occur in electrical and electronic equipment

______d. Fires that occur in combustible metals

1. Class A
2. Class B
3. Class C
4. Class D

6. Match types of fire extinguishers on the right with their uses.

______a. Place foot on foot pump and direct stream at base of fire; use on **class A** fires only.

______b. Direct discharge as close to fire as possible, first at the edge of flames, then gradually forward and upward; use for class B or class C fires.

______c. Instead of spraying stream into the burning liquid, allow foam to fall lightly on the fire; use for class A or class B fires.

______d. Direct at the base of the flames and with a class A fire, follow up by directing the dry chemicals at remaining material that is burning; use for class B or class C fires.

______e. Stand back ten feet, hold upright and direct at the base of fire, sweeping from side to side; use for class C fires

1. Carbon dioxide
2. Halon
3. Pump tank
4. Dry chemical
5. Foam

TEST

7. Match safety colors on the right with the types and hazards they designate.

_____a. 1) Used to identify equipment which is being repaired or is defective and should not be operated

2) Designates "out of order" or "defective"

_____b. 1) Applied to electrical switches, interior surfaces of doors, fuses and electrical power boxes, and movable guards and parts

2) Indicates dangerous parts of equipment which may cut, crush, shock, or otherwise physically injure someone

_____c. 1) Applied to table edges, vise jaws, and edges of tool rests where extra light reflection is important

2) No particular designation except to help show tool and equipment moving edges more clearly

_____d. 1) Applied to nonhazardous part of machine and equipment surfaces, like nameplates and bearing surfaces

2) Designates safe areas of equipment, and is also used to show location of safety equipment and first-aid materials

_____e. 1) Applied to operating levers, wheels, handles, and hazardous parts that may cause stumbling, falling, snagging, or tripping

2) Designates caution

_____f. 1) Applied to buttons or levers of electrical switches used for stopping machinery, and to all equipment, such as gasoline cans, which are fire hazards

2) Designates fire hazards and fire-fighting equipment

1. Green
2. Yellow
3. Orange
4. Red
5. Blue
6. Ivory

TEST

8. Select true statements concerning general safety rules by placing an "X" in the blanks preceding the true statements.

_____a. Report any defective tools, test equipment, or other equipment to the lab partner.

_____b. Do not move any safety devices (i.e. ground straps, switch covers, etc.) without the permission of the instructor.

_____c. Do not operate or energize any circuit that could be hazardous without first receiving instruction on how to do so safely.

_____d. Report all accidents to the instructor if an injury is severe.

_____e. Turn off power before leaving test equipment or circuits being worked on.

_____f. Do not use any solvent without first determining its properties, and how to use it safely.

_____g. Keep the laboratory floor clean of scraps and litter.

_____h. Clean up any spilled liquids before leaving class.

_____i. Isolate line (power) voltages from ground by means of isolation transformers.

_____j. Check all line (power) cords before using and if the insulation is brittle and/or cracked, use and report to the instructor after class.

_____k. When measuring voltages with a meter and test probe, be careful not to connect yourself to a voltage of any value.

_____l. When measuring voltages expected to be greater than 30 volts, turn off or disconnect live circuit before connecting test equipment, or follow manufacturer's recommended procedures.

_____m. It is recommended that only equipment with a polarized (3-prong) plug be used.

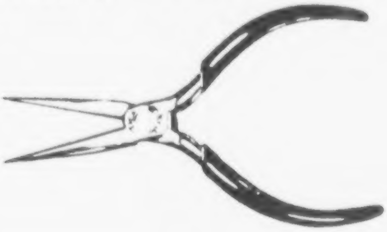
_____n. Carry sharp-edged or pointed tools in your pockets.

_____o. Do not indulge in horseplay or play practical jokes in any work area.

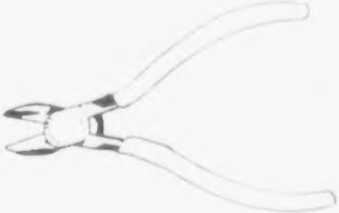
_____p. Wear safety goggles when instructor is watching.

TEST

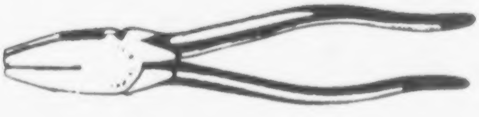
9. Identify the following types of hand tools and equipment by placing their correct names in the appropriate blanks.



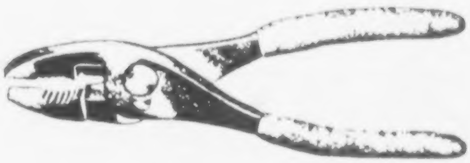
a. ____________________



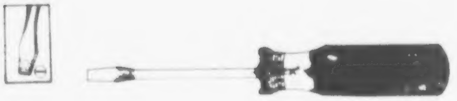
b. ____________________



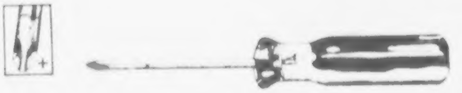
c. ____________________



d. ____________________



e. ____________________

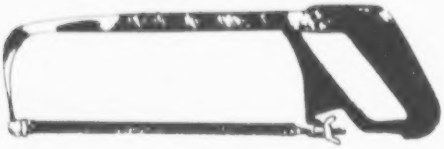


f. ____________________

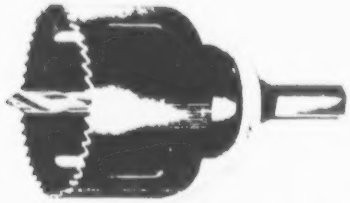
g. ____________________

h. ____________________

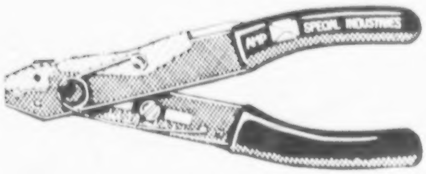
TEST



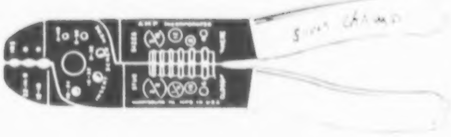
i. ______________________



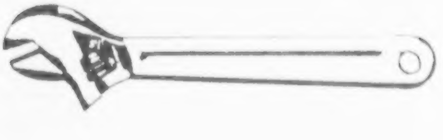
j. ______________________


AMP
SPECIAL INDUSTRIES

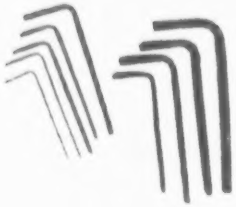
k. ______________________



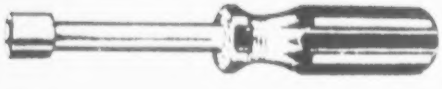
l. ______________________



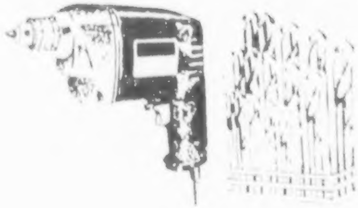
m. ______________________



n. ______________________

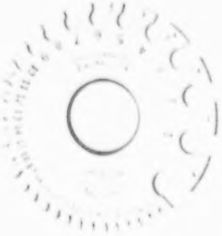


o. ______________________

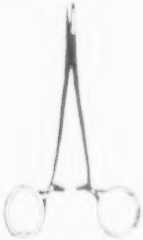


p. ______________________

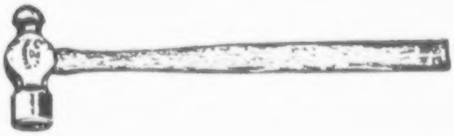
TEST



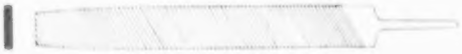
q. ________________________________



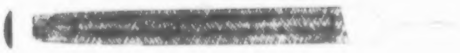
r. ________________________________



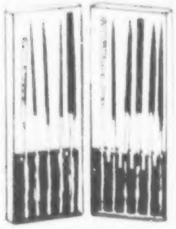
s. ________________________________



t. ________________________________

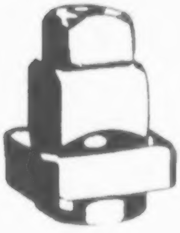


u. ________________________________



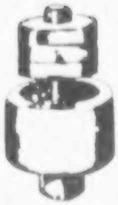
v. ________________________________

w. ________________________________

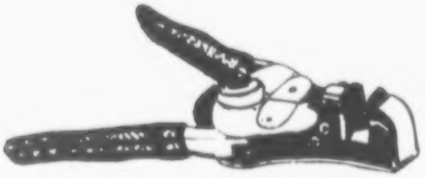


x. ________________________________

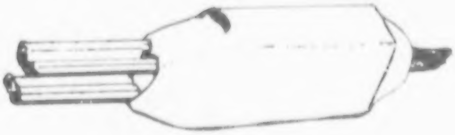
TEST



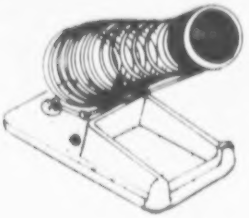
y. ______________________________



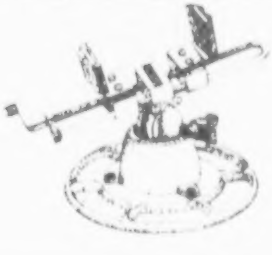
z. ______________________________



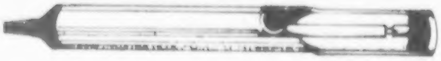
aa. ______________________________



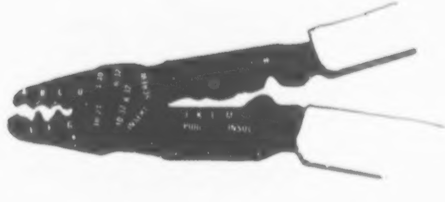
bb. ______________________________



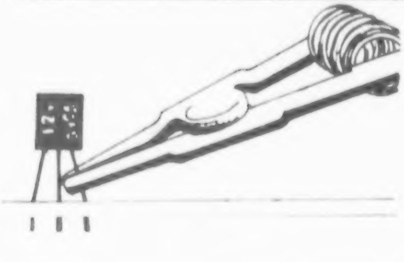
cc. ______________________________



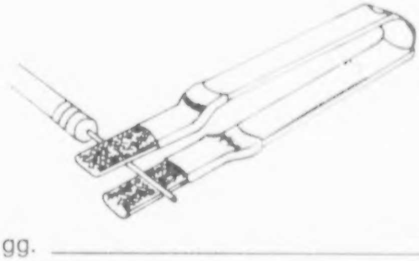
dd. ______________________________



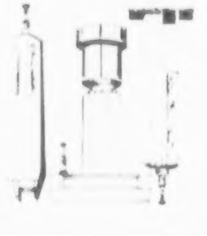
ee. ______________________________



ff. ______________________________



gg. ______________________________



hh. ______________________________

TEST

10. Match hand tools and equipment on the right with their uses.

(NOTE: Answers to questions a. through m. appear on this page.)

_____a. For inserting or removing integrated circuits without bending pins

_____b. For holding nuts or bolt heads; tightening or loosening nuts or bolts

_____c. For preventing electrical connections from becoming shorted to adjacent connections

_____d. For removing oxides and other films from terminals to be soldered

_____e. For holding components; heat sink; and shaping and forming small conductions

_____f. For cutting chassis metal and cutting bolts or metal parts

_____g. For cutting wire and component leads, and stripping insulation from wire

_____h. For clamping and holding a printed circuit board or other component during soldering or other repair operations

_____i. For removing wire insulation by heating and melting the material; prevents wire strands, but cannot be used on insulation that will not melt, such as glass braid or asbestos

_____j. For loosening small to medium size nuts and bolts; holding and turning

_____k. For controlling soldering iron tip temperature

_____l. For cutting and pulling insulation from ends of conductors

_____m. For supporting a hot soldering iron when not in use

1. Insertion or removal tool
2. Hacksaw
3. Diagonal cutting pliers
4. Component lead cleaner
5. Soldering vise
6. Combination slip joint pliers
7. Mechanical wire strippers
8. Shrink tubing
9. Adjustable power source
10. Soldering iron stand
11. Nut drivers
12. Long nose chain pliers
13. Thermal wire strippers

TEST

(NOTE: Answers to questions n. through t. appear on this page.)

_____n. For crimping soldering connections, cutting wire, stripping insulation from wire, shearing bolts, thread gauges, and length gauges for stripping

_____o. For cutting heavier conductors and cables, cutting small screws, stripping insulation from wires, and forming large conductors

_____p. For cutting holes up to four inches in diameter; punching round or square holes in metal

_____q. Removing or tightening screws and bolts

_____r. For tightening or loosening socket cap screws; tightening or loosening set screws

_____s. For drawing heat from soldered connection to prevent damage to components

_____t. For making a strong mechanical connection to certain sleeve-type terminals

14. Lineman's side cutting pliers
15. Hole saws and hole punches
16. Hex and spline wrenches
17. Electrician's six-in-one tool
18. Heat sink
19. Screwdrivers
20. Crimping tool

11. Select true statements concerning factors to consider when selecting hand tools by placing an "X" in the blanks preceding the true statements.

_____a. Tool size should be matched to the work occasionally encountered.

_____b. Tools should have insulation on handles of pliers and screwdrivers.

_____c. Know the specifications after purchasing a tool.

12. Complete the following list of statements concerning tool maintenance procedures by inserting the word(s) which best complete(s) each statement.

a. ____________ worn or damaged flat blade screwdrivers.

b. ____________ damaged Phillips* screwdrivers.

c. Keep ____________ clean and rust free.

d. Keep cutting edges sharp and ____________.

e. Keep ____________ working freely.

TEST

f. Repair or replace damaged ____________ ____________ on pliers.

g. Keep worm gears clean and ____________ on adjustable wrenches.

h. Identify tools by labeling with an electrical vibrator pen or ____________ ____________.

13. Match types of soldering tools on the right with their uses.

______a. 10 to 36 watts — For soldering isolated electrical connections; eliminates electrical leakage and the need for grounding

______b. 10 to 36 watts — For soldering small electrical connections

______c. 100 watts — For soldering large electrical connections when better heat control is required

______d. For soldering many connections in close space

1. Temperature controlled
2. Soldering pencil
3. Soldering gun
4. ISO-TIP

14. Select true statements related to solder and flux by placing an "X" in the blanks preceding the true statements.

______a. The most common type of solder is 40/60 rosin core solder containing 40% tin and 60% lead

______b. Solder for electronic applications is available in bars, sheets, wire spools and special forms such as pellets, rings, and washers.

______c. Wire solders in the range from 0.060" to 0.10" in diameter are commonly used for hand soldering.

______d. Flux is a chemical agent used to remove the thin films of oxide present on the metal surfaces to be soldered.

______e. Organic (acids and bases) fluxes are the most active and highly corrosive fluxes; they absorb moisture from the atmosphere and react strongly at room temperature.

______f. Rosin is used almost exclusively for its noncorrosive characteristics at room temperature.

15. List three primary purposes for solder in electrical applications.

a. ____

b. ____

c. ____

TEST

16. Arrange in order the following safe soldering procedures by indicating the first step as 1, the second as 2, and so on for each procedure.

_____a. Prepare area to be soldered.

1) Remove surface contaminants and oxides.

2) Apply liquid flux to area to be soldered.

_____b. Select the soldering iron for a specific application.

_____c. Place small amount of solder on tip of iron to aid heat transfer.

_____d. Prepare soldering tip prior to use by a process termed tinning.

_____e. Place tip of iron next to terminal area and lead.

_____f. Remove solder from heat after it has flowed and formed a smooth contour of solder around the lead and terminal pad.

_____g. Allow soldered area to cool.

_____h. Remove contaminated flux residue from soldered area.

_____i. Place solder on opposite side of the lead.

_____j. Remove soldering iron.

17. Distinguish between types of connections by placing an "N" for no mechanical connection, a "P" for partial mechanical connection, and an "F" for full mechanical connection prior to soldering next to their specific types.

_____a. Wire-to-wire

_____b. Wire-to-part

_____c. Wire-to-turret or post

_____d. Wire-to-hole

_____e. Wire-to-cup or sleeve

_____f. Wire-to-hook

_____g. Wire-to-flatlug

TEST

18. Select true statements concerning types of desoldering tools and their processes by placing an "X" in the blanks preceding the true statements.

______a. The desoldering bulb is used to remove excess solder from the connection.

______b. The solder sucker is used in the same manner as the desoldering bulb except that the suction is produced by a spring loaded piston.

______c. On the desoldering bulb, the liquid solder is drawn up into the bulb by the suction.

______d. The solder wick is placed over terminal area and lead to be desoldered.

______e. The solder wick is used for desoldering component leads.

19. Complete the following chart of cleaners and lubricants by correctly filling in the blanks.

Cleaners	*Type*	*Application*
a. ______	Petroleum solvent	Cleaning solder connections Thinner for shellac and rosin
Isophorone	b. ______	Wash-up for vinyl inks
c. ______	Petroleum solvent	For removing oil, grease, and flux from conductors and terminals both before and after soldering
d. ______	Petroleum solvent	Machine cutting fluid
Sodium hydroxide	e. ______	Cleaning and etching aluminum
f. ______	Chlorinated solvent	General-purpose cleaner and vapor degreaser
Xylene	g. ______	Thinner for acrylic printing inks Wash-up for synthetic enamels and photo resist ink

Lubricant	*Application*
h. ______	General purpose lubricant

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

20. Demonstrate the ability to:

    a. Prepare a soldering iron tip for use. (Job Sheet #1)

    b. Adjust wire strippers. (Job Sheet #2)

    c. Strip and tin wires for soldered connections. (Job Sheet #3)

    d. Solder wires to turret terminals, then desolder wires. (Job Sheet #4)

    e. Splice wires together by means of soldering and crimping (flat cable). (Job Sheet #5)

    f. Repair a printed circuit board. (Job Sheet #6)

SHOP ORIENTATION AND SAFETY PRINCIPLES
UNIT I

ANSWERS TO TEST

1. a. 13
   b. 8
   c. 7
   d. 10
   e. 2
   f. 4
   g. 12
   h. 9
   i. 3
   j. 1
   k. 5
   l. 6
   m. 11
   n. 23
   o. 15
   p. 14
   q. 16
   r. 21
   s. 18
   t. 22
   u. 20
   v. 19
   w. 17

2. a. Electrical shock
   b. Electrical burns
   c. Electrical fires
   d. Injury from misuse of tools
   e. Chemical burns or poisoning
   f. Gas inhalation

3. a. Current, voltage
   b. Voltage
   c. Current
   d. 10

4. a, b, e, g

5. a. 1
   b. 2
   c. 3
   d. 4

6. a. 3
   b. 1
   c. 5
   d. 4
   e. 2

7. a. 5
   b. 3
   c. 6
   d. 1
   e. 2
   f. 4

8. b, c, e, f, g, i, k, l, m, o

ANSWERS TO TEST

9. a. Long nose chain pliers
   b. Diagonal cutting pliers
   c. Lineman's side cutting pliers
   d. Combination slip joint pliers
   e. Flat blade screwdriver
   f. Phillips® head screwdriver
   g. Torx® driver
   h. Pozidriv®
   i. Hacksaw
   j. Holesaw
   k. Adjustable wire strippers
   l. Electrician's six-in-one tool
   m. Adjustable wrench
   n. Wrenches
   o. Nut driver
   p. Drill and drill bits
   q. Wire gauge
   r. Hemostat clamp
   s. Ballpeen hammer
   t. Flat file
   u. Half-round file
   v. Precision file
   w. Center punch
   x. Square hole punch
   y. Round hole punch
   z. Mechanical wire strippers
   aa. Thermal wire strippers
   bb. Soldering iron stand
   cc. Soldering vise
   dd. Solder sucker
   ee. Crimping tool
   ff. Heat sink
   gg. Component lead cleaner
   hh. Insertion tools

10.

10.	a. 1		h. 5		o. 14	
	b. 11		i. 13		p. 15	
	c. 8		j. 6		q. 19	
	d. 4		k. 9		r. 16	
	e. 12		l. 7		s. 18	
	f. 2		m. 10		t. 20	
	g. 3		n. 17			

11. b

12.

12.	a.	Regrind	e.	Pliers
	b.	Discard	f.	Handle insulation
	c.	Pliers	g.	Lubricated
	d.	Smooth	h.	Scratch awl

ANSWERS TO TEST

13. a. 4
    b. 2
    c. 3
    d. 1

14. b, d, f

15. Any three of the following:
    a. Makes connections with virtually no resistance to electrical current flow
    b. Prevents corrosion of conductors, connections, and parts
    c. Makes connections mechanically stronger
    d. Seals containers to keep out dust and moisture

16. a. 3 f. 7
    b. 1 g. 9
    c. 4 h. 10
    d. 2 i. 6
    e. 5 j. 8

17. a. N
    b. N
    c. P, F
    d. N
    e. N
    f. P
    g. P, F

18. b, c, d

19. a. Ethyl alcohol
    b. Petroleum solvent
    c. Isopropyl alcohol
    d. Kerosene
    e. Alkaline solvent
    f. Trichlorethylene
    g. Petroleum solvent
    h. WD40 or 3-in-1 oil

20. Performance skills evaluated to the satisfaction of the instructor

INTRODUCTION TO DC
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to determine resistance and capacitance using the resistor color code, apply Ohm's law, and use a voltmeter and ammeter. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to introduction to DC with their correct definitions.
2. Match common parameters used in electronics with their correct symbols and units of measure.
3. Complete a chart of numerical decimal equivalents and powers of ten prefixes.
4. State the number which corresponds to the correct color in the resistor color code.
5. Determine resistance using the resistor color code.
6. Match basic circuit elements with their symbols.
7. List the two types of resistors.
8. Complete a list of meter ranges for analog and digital meters.
9. Match types of meter scales with their correct uses.
10. Arrange in order the general steps used in preparing a multimeter for operation.
11. Distinguish between a voltmeter and ammeter.

OBJECTIVE SHEET

12. Arrange in order the procedures for measuring voltage.
13. Select from a list procedures for measuring amperage.
14. Complete a list of procedures for measuring resistance.
15. Select true statements concerning amperage measurement characteristics.
16. Complete a list of voltage measurement characteristics.
17. State Ohm's law.
18. List three uses of Ohm's law.
19. Select true statements concerning magnetic properties.
20. Discuss the use of the left-hand rule for conductors and coils.
21. Complete a list of statements concerning the method and effect of induction.
22. Match types of grounds with their correct descriptions.
23. Match static electricity controls with their correct uses.
24. Solve problems for an unknown voltage, amperage, and resistance. (Assignment Sheet #1)
25. Calculate the resistance values from given color codes. (Assignment Sheet #2)
26. Read analog voltmeter scales. (Assignment Sheet #3)
27. Convert amperes to milliamps and microamps. (Assignment Sheet #4)
28. Read analog ammeter indications. (Assignment Sheet #5)
29. Demonstrate the ability to:
    a. Measure and compare current in a circuit at two different voltage levels. (Job Sheet #1)
    b. Wire a functional relay circuit. (Job Sheet #2)
    c. Measure the voltage drop in a DC circuit. (Job Sheet #3)
    d. Demonstrate that magnetic poles can attract and repel. (Job Sheet #4)
    e. Construct a simple electromagnet and check its operation. (Job Sheet #5)

INTRODUCTION TO DC
UNIT II

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Help students memorize the color code for resistors using a mnemonic (memory) device such as the following:

   Bad **B**oys **R**ace **O**ur **Y**oung **G**irls, **B**ut **V**iolet **G**enerally **W**ins.

   0 1 2 3 4 5 6 7 8 9

   You or your students may wish to make up a device of your own, but it should be stressed to the students that they must memorize this color code, and this is one way to help.

2. Show students examples of resistors and have them identify the various types.
3. Explain test lead connections to students.
4. Demonstrate the use of the left-hand rule for conductors and coils.
5. Show examples of static electricity controls and discuss their benefits.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM 1 — Resistor Color Code
2. TM 2 — Analog Multimeter
3. TM 3 — Digital Multimeter
4. TM 4 — Correct Voltage Measurements
5. TM 5 — Correct Amperage Measurements
6. TM 6 — Correct Resistance Measurements
7. TM 7 — Magnetic Lines of Force
8. TM 8 — Induction

E. Assignment sheets

1. Assignment Sheet #1 — Solve Problems For an Unknown Voltage, Amperage, and Resistance
2. Assignment Sheet #2 — Calculate the Resistance Values From Given Color Codes
3. Assignment Sheet #3 — Read Analog Voltmeter Scales
4. Assignment Sheet #4 — Convert Amperes to Milliamps and Microamps
5. Assignment Sheet #5 — Read Analog Ammeter Indications

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Measure and Compare Current in a Circuit at Two Different Voltage Levels
2. Job Sheet #2 — Wire a Functional Relay Circuit
3. Job Sheet #3 — Measure the Voltage Drop in a DC Circuit
4. Job Sheet #4 — Demonstrate That Magnetic Poles can Attract and Repel

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

5. Job Sheet #5 — Construct a Simple Electromagnet and Check its Operation

H. Test

I. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

(NOTE: The following is a list of references used in completing this unit.)

A. Grob, Bernard. *Basic Electronics*. New York: McGraw-Hill Book Co.

B. Hall, Douglas V. *Microprocessors and Digital Systems*. New York: McGraw-Hill, 1983.

C. Herrich, Clyde N. *Instruments and Measurements for Electronics*. New York: McGraw-Hill, 1972.

D. Horvath, T. *Static Elimination*. Letchworth, England: Research Studies Press, 1982.

E. New Mexico Vocational Industrial Safety Guide. Santa Fe, NM: New Mexico State Department of Education.

F. Robertson, L. Paul. *Basic Electronics I (Revised Edition)*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

G. Siebert, Leo N. *Introduction to Industrial Electricity-Electronics*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1981.

INTRODUCTION TO DC
UNIT II

INFORMATION SHEET

I. **Terms and definitions**

A. Accuracy — How near the instrument reading is to the actual value

B. Applied voltage — Total voltage supplied to a circuit; also referred to as supply voltage or source voltage

C. Ampere — Basic unit of electric current

(NOTE: One ampere of current flows when one volt of potential is applied across one ohm of resistance.)

D. Calibration — Technique of testing and adjusting an instrument by referencing it to another instrument or device of known accuracy and precision

E. Electromagnet — A core of soft iron that is temporarily magnetized by sending current through a coil of wire wound around the core

F. Error — How far the measurement is from the actual value

G. Ground — Common return to earth for AC power lines; chassis ground in electronic equipment is the common return to one side of the internal power supply

H. Internal resistance — Total resistance offered by a device; is normally associated with the power source

I. Magnet — An object which will attract iron, nickel, or cobalt and which will produce an external magnetic field

J. Magnetic field — The area around a magnet through which the lines of force flow

K. Magnetism — A property of certain materials which exerts a mechanical force on other materials and which can cause induced voltages in conductors when relative movement is present

L. Multimeter — Instrument capable of measuring a "multiple" of values

Example: Amperage, voltage, and resistance with several measurement ranges

M. Ohms — Unit of measure for resistance

N. Parameter — A specified element or condition which determines the value of circuit variables

O. Potential difference — The electromotive force developed between two points that moves electric current through a load that is connected across a source

INFORMATION SHEET

P. Range — Establishes the limits of a scale

Q. Resistance — Opposition to current

R. Resolution — How well the instrument will indicate a small change in the measured value

Example: A precise, accurate, and sensitive meter may respond by moving the meter hand $^{1}/_{16}$" for a small change in measured amperage. If the scale is marked only one division per inch, the mete would still lack "resolution" since the operation could not determine what amount of current change this represents.

S. Sensitivity — How well an instrument responds to small measurements or small changes in the value being measured

T. Short circuit — An abnormal connection of relatively low resistance between two points of differing potential in a circuit

U. Static electricity — The storage of electrical energy

(NOTE: Static electricity in an uncontrolled environment can damage some electronic components. The human body can accumulate a static charge that is lethal to these sensitive components. By walking across the floor (carpeted floors especially) and wearing nylon or polyester clothing, the human body can reach a 10-15 KV potential. This potential can cause a spark of 10-100 amps and last 10^{-8} · 10^{-9} seconds.)

V. The reciprocal of a number — One (1) divided by that number

Example: The reciprocal of 2 is $^{1}/_{2}$ (one divided by two) or .5

The reciprocal of 4 is $^{1}/_{4}$ (one divided by four) or .25

W. Tolerance — The acceptable amount of variation from an indicated value

X. Variable — Changeable or capable of being changed

(NOTE: A resistor whose value can be changed is called a variable resistor or potentiometer.)

Y. Volt — The unit of measurement of electromotive force

(NOTE: One volt forces one ampere of current through one ohm of resistance.)

Z. Voltage — Electrical force or pressure that causes the flow of electrical current (electrons)

AA. Voltage drop — Difference in voltage measured across a component in a circuit

INFORMATION SHEET

II. Common parameters used in electronics

QUANTITY	SYMBOL	UNIT (ACCEPTED ABBREVIATION)
Current	I or i	Ampere (A)
Charge	Q or q	Coulomb (C)
Power	P	Watt (W)
Voltage drop	V or v	Volt (V)
Voltage applied	E	Volt (V)
Resistance	R	Ohm (Ω)
Reactance	X	Ohm (Ω)
Impedance	Z	Ohm (Ω)
Conductance	G	Siemens (S)
Admittance	Y	Siemens (S)
Susceptance	B	Siemens (S)
Capacitance	C	Farad (F)
Inductance	L	Henry (H)
Frequency	f	Hertz (Hz)
Period	T	Seconds (s)

III. Numerical decimal equivalents and powers of ten prefixes

UNIT PREFIX	SYMBOL	MULTIPLIER
Giga	G	1,000,000,000 [10^{9}]
Mega	M	1,000,000 [10^{6}]
Kilo	K	1,000 [10^{3}]
Milli	m	.001 [10^{-3}]
Micro	μ (Greek, μ)	.000001 [10^{-6}]
Nano	η	.000000001 [10^{-9}]
Micromicro or pico	$\mu\,\mu$ or ρ	.000000000001 [10^{-12}]

Examples: A 220,000 ohm resistor could be represented as 220K or .22M. A .25 watt resistor could be represented as 250 mW.

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IV. **Resistor color code** (Transparency 1)

- A. Black — 0
- B. Brown — 1
- C. Red — 2
- D. Orange — 3
- E. Yellow — 4
- F. Green — 5
- G. Blue — 6
- H. Violet — 7
- I. Gray — 8
- J. White — 9
- K. Gold — .1
- L. Silver — .01

(NOTE: The following refer to tolerance band.)

- M. Gold — ± 5%
- N. Silver — ± 10%
- O. No color — ± 20%

V. **Determining resistance using the resistor color code** (Transparency 1) (Assignment Sheet #2)

A. First color band (closest to end) is first significant digit — Use color code to convert color to a number

Example: If first band is red, this converts to a 2.

B. Second color band is second significant digit — Use color code to convert color to a number

Example: If second band is brown, this converts to a 1.

C. Third color band is the multiplier — Use color code to convert color to a number which is the exponent of 10 or the number of zeros to be added to the significant numbers

Example: If third band is orange, this converts to a 3; this is 10^3 or there are 3 zeros.

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D. Fourth color band is the tolerance

1. If band is gold, tolerance is ±5%

2. If band is silver, tolerance is ±10%

3. If there is **no** band, tolerance is ±20%

Example: For a resistor with the first band red, second band brown, third band orange and the fourth band one of the following then the acceptable resistor measurement would range between:

1. Gold — 19 000 and 21 000 ohms
2. Silver — 18 000 and 22 000 ohms
3. No band — 16 000 and 24 000 ohms

E. Fifth color band

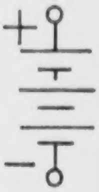
1. In military applications the fifth band indicates the failure rate.

2. In precision resistors the fifth band indicates the tolerance and the first, second, and third bands represent the significant digits with the fourth band as the multiplier.

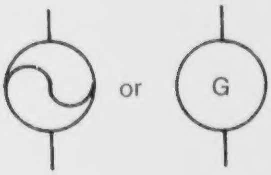
VI. Basic circuit elements and their symbols

A. Power sources

1. Battery

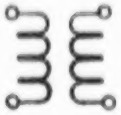


2. Generator



INFORMATION SHEET

3. Transformer

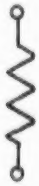


B. Load

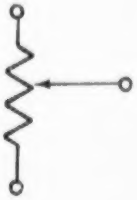
(NOTE: All wires used in the electrical circuit provide a certain amount of resistance to current. All the devices connected to the circuit to produce light or heat offer resistance to current flow. This is called load.)

1. Resistor

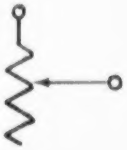
   a. Fixed



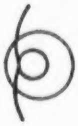
   b. Resistor potentiometer



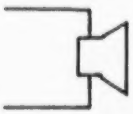
   c. Rheostat



2. Lamp/light



3. Loudspeaker

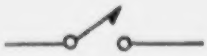


INFORMATION SHEET

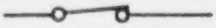
C. Circuit switches

(NOTE: In the switch open position, current cannot flow through the circuit. In the switch closed position, current can flow through the circuit. These are hand operated switches.)

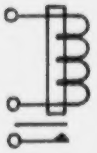
1. Switch open



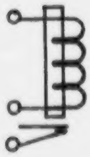
2. Switch closed



3. Relay open



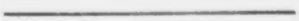
4. Relay closed



(NOTE: The relay open and relay closed are electrically operated switches.)

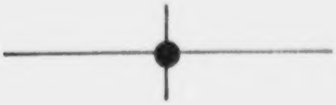
D. Circuit conductors (wires)

1. Conductor



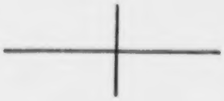
INFORMATION SHEET

2. Conductors connected

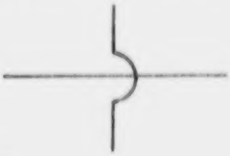


or

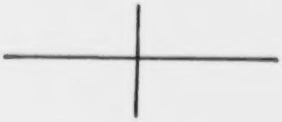
Conductors not connected



3. Conductors not connected



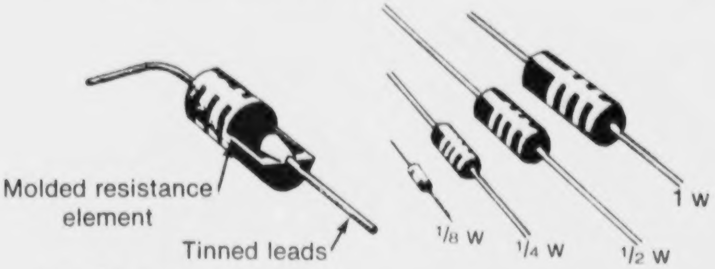
Conductors connected



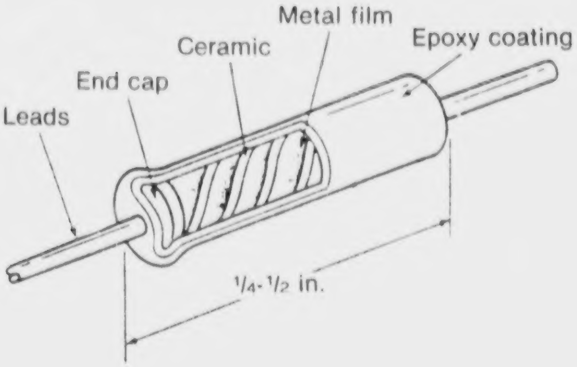
VII. **Types of resistors**

A. Fixed

1. Carbon-composition resistors


Molded resistance element
Tinned leads
1/8 w
1/4 w
1/2 w
1 w

2. Carbon-film resistor


Metal film
Epoxy coating
Ceramic
End cap
Leads
1/4-1/2 in.

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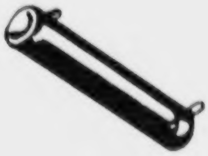
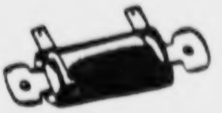
3. Wire-wound resistor

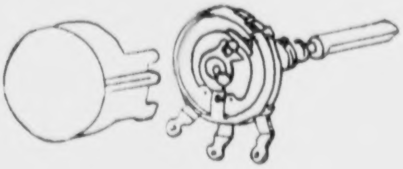


4. Film-element resistor

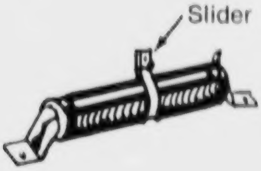


B. Adjustable

1. Carbon-composition potentiometer

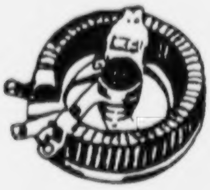


2. Wire-wound variable resistor

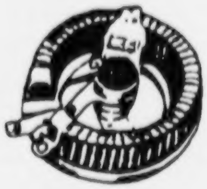


INFORMATION SHEET

3. Wire-wound potentiometer



4. Wire-wound rheostat



VIII. **Meter ranges for analog and digital meters**

(CAUTION: Proper meter connections must be established to avoid damage to analog meters.)

A. DC voltage ranges

1. Analog — 2.5, 10, 50, 250, 1000, and 5000 volts (Transparency 2)

   (NOTE: The ranges given are for a Simpson 260. DC voltage measurements above 1000 volts put the red lead into the 5000 volt DC terminal.)

2. Digital — 200mV, 2, 20, 200, and 1000 volts (Transparency 3)

B. AC voltage ranges

1. Analog — 2.5, 10, 50, 250, 1000, and 5000 volts

   (NOTE: AC voltage measurements above 1000 volts put the red lead into the 5000 AC terminal.)

2. Digital — 200mV, 2, 20, 200, and 750 volts

C. DC milliamps range

1. Analog — 1mA, 10mA, 50mA, 100mA, 500mA, and 10A

2. Digital — 200A, 2mA, 20mA, 2A and 10A

   (NOTE: For measurements greater than one ampere, plug the red lead into the 10A terminal.)

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D. AC milliamps range

1. Analog — 1mA, 10mA, 50mA, 100mA, 500mA, and 10A

   (NOTE: For measurements greater than one amp, plug the red lead into the 10A terminal.)

2. Digital — 200A, 2mA, 20mA, 2A, and 10A

   (NOTE: For measurements greater than one amp, plug the red lead into the 10A terminal.)

E. Ohm ranges

1. Analog — X1, X100, X1 000, and X10 000
2. Digital — O-200, O-2K, O-20K, O-200K, O-2 000K, and O-20M

IX. **Types of meter scales** (Transparencies 2 and 3)

A. 2.5 volt AC scale — Used to do nonlinear indications below 2 volts

B. DB scale — Used for power level measurements

C. Ohm's scale — Used for resistance measurements. Zero readings will always indicate a short. Readings at the left most side of the scale indicate infinite resistance or an open.

(NOTE: When using an analog meter the most accurate readings are obtained when a range is chosen that provides an indication on the right-hand portion of the scale.)

D. DC scale — Used for direct current/voltage measurements

E. AC scale — Used for alternating current/voltage readings

X. **General steps used in preparing a multimeter for operation** (Transparencies 2 and 3)

A. Select function to be measured.

Examples: Volts, amps, milliamps, ohms, megohms

B. Select the range or anticipated limits of measurement required.

Examples: 500 mA, 20V., or ×100Ω

(NOTE: Some multimeter range switches also select certain functions. [Transparency 2].)

C. Connect test leads to proper test jacks.

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D. Make necessary meter adjustments.

Examples: Set "Ohms Zero Adjust" for a zero ohms reading with meter prepared for ohms measurement and leads connected to each other

(NOTE: "Meter zero" and "zero ohms" readings are at opposite ends of the scale.)

XI. **Characteristics of meters**

A. Voltmeter

1. High resistance to current flow
2. Range can be increased by adding a series resistance
3. Measures across the circuit or device

B. Ammeter

1. Low resistance to current flow
2. Range can be increased by adding a parallel (shunt) resistance
3. Measures in series with the circuit or device

XII. **Procedures for measuring voltage** (Transparency 4)

A. Position meter to correct function.

Examples: −DC, +DC, or AC

B. Observing polarity, connect meter leads to meter.

C. Determine correct range and scale.

(NOTE: Use highest range if voltage is unknown. Connect voltmeter across the component or power source to be tested. Turn off power when installing or removing meter leads whenever possible.)

D. Observing polarity, connect meter leads to circuit to be tested.

E. Set meter on lowest scale at which it will register.

F. Read correct voltage.

G. Disconnect meter leads.

H. Turn off meter.

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XIII. **Procedures for measuring amperage** (Transparency 5)

A. Turn off power to circuit under test.

B. Position meter to correct scale.

C. Determine correct range.

(NOTE: Use highest scale if amperage is unknown.)

D. Observing polarity, connect test leads to meter.

E. Connect meter in circuit to be tested, observing polarity and connecting in series with the circuit.

F. Turn on equipment under test.

G. Observe meter reading.

H. Position range switch to correct scale for most accurate reading.

I. Determine correct amperage reading.

J. Turn off power to equipment.

K. Disconnect meter.

L. Reconnect circuit.

M. Turn off meter.

XIV. **Procedures for measuring resistance** (Transparency 6)

A. Turn off power to circuit under test.

(CAUTION: Be sure circuit is totally de-energized.)

B. Position meter to the correct function position.

C. Position meter range switch to one of the resistance scales.

D. Insert meter leads in correct meter jacks, observing polarity.

E. Isolate component to be checked.

Example: Disconnect one end of component

F. Connect meter across component to be measured.

G. Determine correct meter position closest to center scale or toward zero.

H. Perform zero ohms adjustment according to manufacturer's manual.

I. Reconnect meter to component.

J. Read meter for ohmic value.

K. Remove meter leads.

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- L. Turn off meter.
- M. Reconnect component in circuit.

XV. **Amperage measurement characteristics (directly in series)** (Transparency 5)

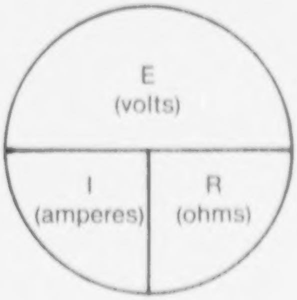
- A. All current passes through the ammeter.
- B. Technique is limited to small measurements.
- C. Alternating current or direct current can be measured.

XVI. **Voltage measurement characteristics (direct parallel measurement)** (Transparency 4)

- A. Voltmeter probes connect directly across terminals.
- B. Techniques limited to moderate AC or DC voltages.

XVII. **Ohm's law — The current (amperes) in an electric circuit equals the electromotive force or potential (volts) divided by the resistance (ohms)**

Example:



$$E = IR$$

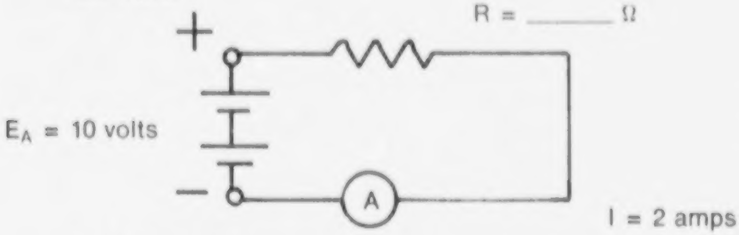
$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

XVIII. **Uses of Ohm's law** (Assignment Sheet #1)

A. Calculating circuit resistance

Example:



What is the resistance value of the resistor in this circuit?

$$R = \frac{E}{I} = \frac{10 \text{ volts}}{2 \text{ amperes}} = 5\,\Omega$$

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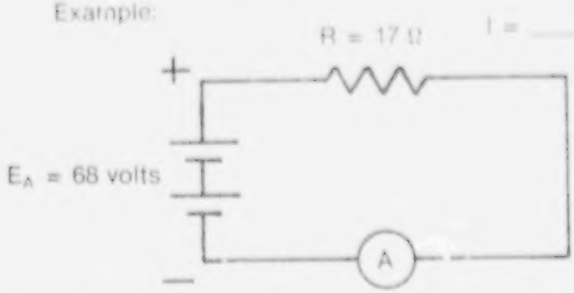
B. Calculating circuit amperage

Example:

I = ______ amps



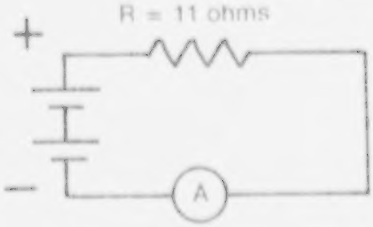
How many amperes of current are flowing in this circuit?

$I = \frac{E}{R}$ $I = \frac{68 \text{ volts}}{17 \text{ ohms}} = 4$ amperes

C. Calculating circuit voltage

Example:

E = ______ volts



I = 2 amps

What voltage is being supplied by the battery?

$E = IR = 2$ amperes × 11 ohms = 22 volts

The value of the voltage being supplied by the battery is 22.

XIX. **Magnetic properties**

A. Magnetic lines of force (Transparency 7)

1. Are continuous and form complete loops
2. Never cross each other
3. Cause like poles (north-north, south-south) to repel each other
4. Cause unlike poles (north-south, south-north) to attract each other

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   5. Parallel lines going in the same direction repel each other

   6. Attract other lines going in the opposite direction

   7. Exert tension along their lengths, tending to shorten themselves

      (NOTE: If the two poles of a magnet could move, the lines of force would eventually pull the two poles together.)

   8. Pass through all materials, both magnetic and nonmagnetic

   9. Always enter or leave magnetic material at right angles to the surface

   10. Tend to flow in paths of least opposition

B. Magnetic field

   1. Area around magnet through which force lines flow

   2. Direction of flow is always from north pole to south pole, except internally

C. Magnetic flux

   1. Sum total of magnetic field force lines flowing from north pole to south pole

   2. Symbol for magnetic flux — Greek letter phi (Φ)

   3. Unit of flux — Maxwell; one maxwell (Mx) equals one line of force

      Example: If a magnetic field contains 6 lines of force, the flux of the magnet is 6 maxwells, or $\Phi = 6Mx$

   4. Flux density — Number of force lines per given area

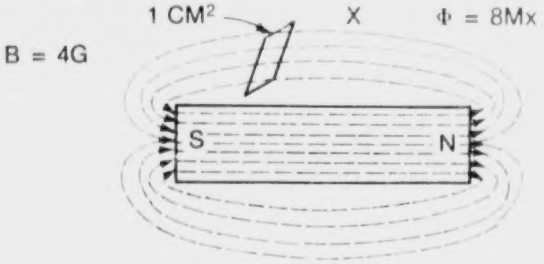
      a. Symbol — B

      b. Unit of flux density — Gauss (G); one gauss (G) equals one force line per square centimeter

      c. In the magnetic field shown on the following page, total magnetic flux (from point X to point Y) is 8 lines of force, or 8 maxwells, expressed as $\Phi = 8Mx$.

INFORMATION SHEET

d. The flux density (B) in one square centimeter (1 cm^2) equals 4 gauss, expressed as $B = 4G$.



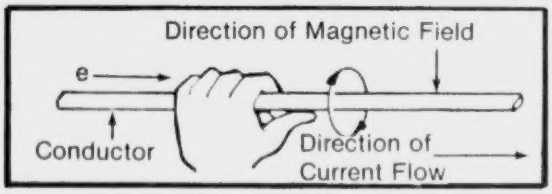
(NOTE: A typical one pound magnet might have a magnetic flux of 5000 maxwells, and a flux density of 1000 gauss.)

XX. The use of the left-hand rule for conductors and coils

A. Left-hand rule for conductors

1. Grasp conductor with left hand as shown, making sure thumb is pointing in direction of electron flow in the conductor.

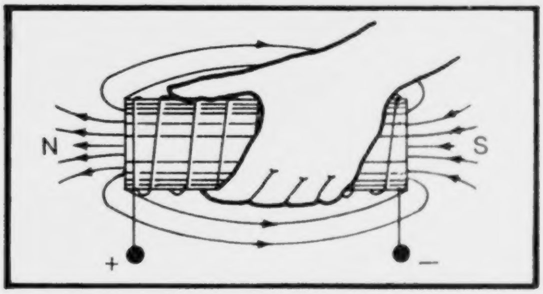
2. Direction of magnetic field flow is in the direction of the four fingers, from large knuckles toward fingertips.



B. Left-hand rule for coils

1. Grasp the coil with left hand as shown below so that the four fingers (from knuckles to fingertips) point in direction of electron flow through the coiled conductor.

2. The thumb now points toward the north pole of the electromagnet.



(CAUTION: Do not wrap hand around an energized coil.)

INFORMATION SHEET

XXI. Method and effect of induction (Transparency 8)

A. Method

1. Place iron bar in vicinity of permanent magnet.
2. Do not allow iron bar to touch magnet.

B. Effect

1. Magnetic field lines of force flow through the iron bar.
2. The iron bar becomes electromagnetized.
3. Pole polarity is reversed.
    a. End of bar near north pole of magnet becomes south pole of bar.
    b. End of bar near south pole of magnet becomes north pole of bar.
4. The permanent magnet attracts the iron bar.

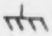
(NOTE: This constitutes more action.)

XXII. Types of grounds

(NOTE: A ground permits the generation of both positive and negative voltages.)

A. Signal or common ground ( ) — Voltage reference point or current return

B. Earth ground ( ) — A rod or pipe that is buried in the earth

C. Chassis ground () — Connected to a metal chassis or outer cabinet enclosure

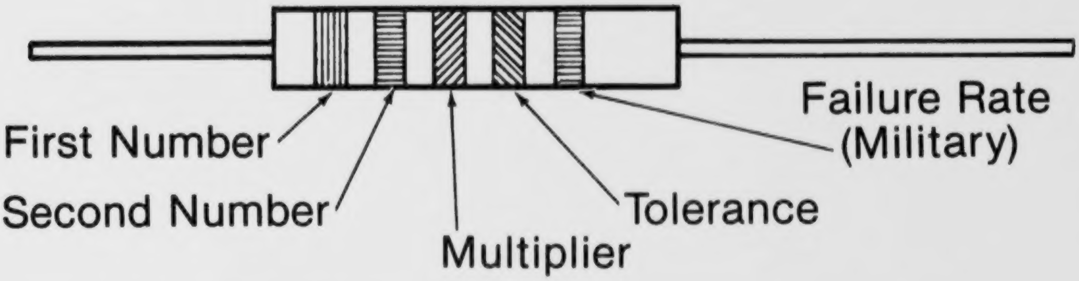
XXIII. Static electricity controls

A. Wrist straps — Integrate personnel into grounding system

B. Stool covers, bench tops, and ground cords — Give parallel leakage paths

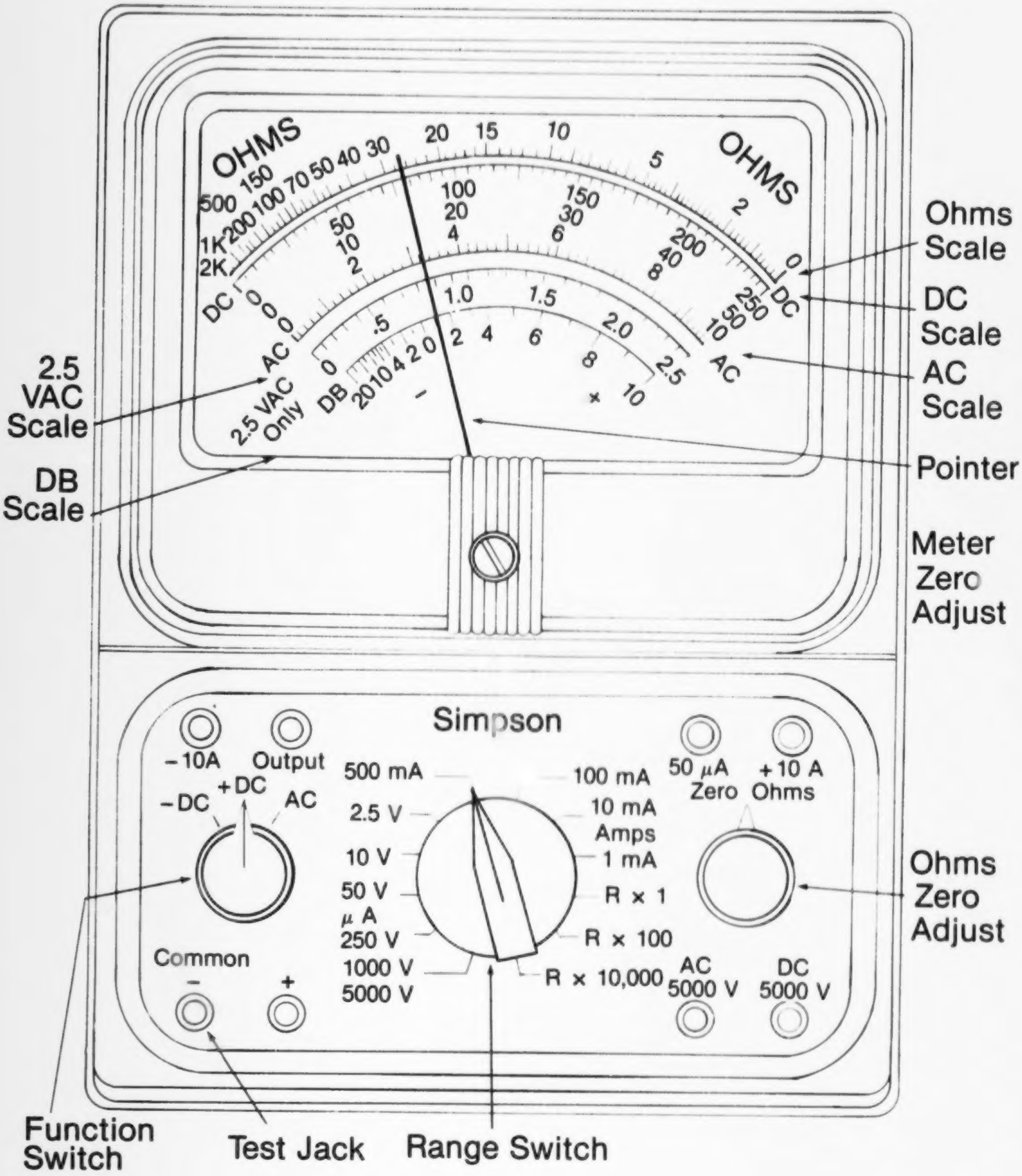
C. Air ionizers — Used to ionize the air around an immediate work area where electrostatic sensitive components are used

Resistor Color Code

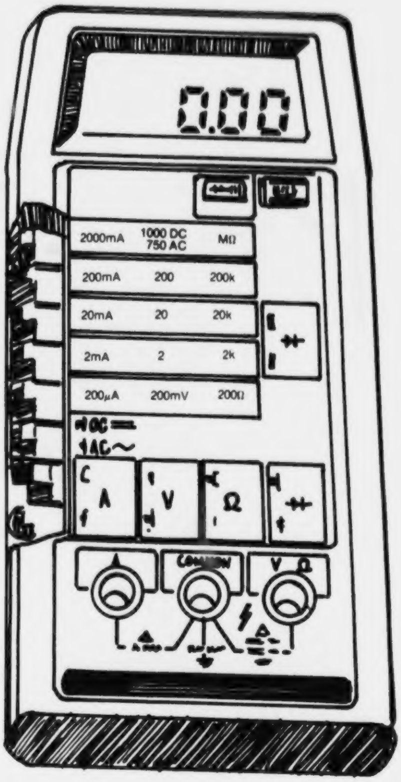

First Number
Second Number
Multiplier
Tolerance
Failure Rate (Military)

Color	First Number	Second Number	Multiplier	Tolerance	Failure Rate per 1000 hrs.
Black	0	0	1	± 20%	L 5%
Brown	1	1	10	± 1%	M 1%
Red	2	2	100	± 2%	P 0.1%
Orange	3	3	1000	—	R 0.01%
Yellow	4	4	10000	—	S 0.001%
Green	5	5	100000	—	T 0.0001%
Blue	6	6	1000000	—	
Violet	7	7	10000000	—	
Gray	8	8		—	
White	9	9		—	
Gold	—	—	0.1	± 5%	
Silver	—	—	0.01	± 10%	
No Color	—	—	—	± 20%	

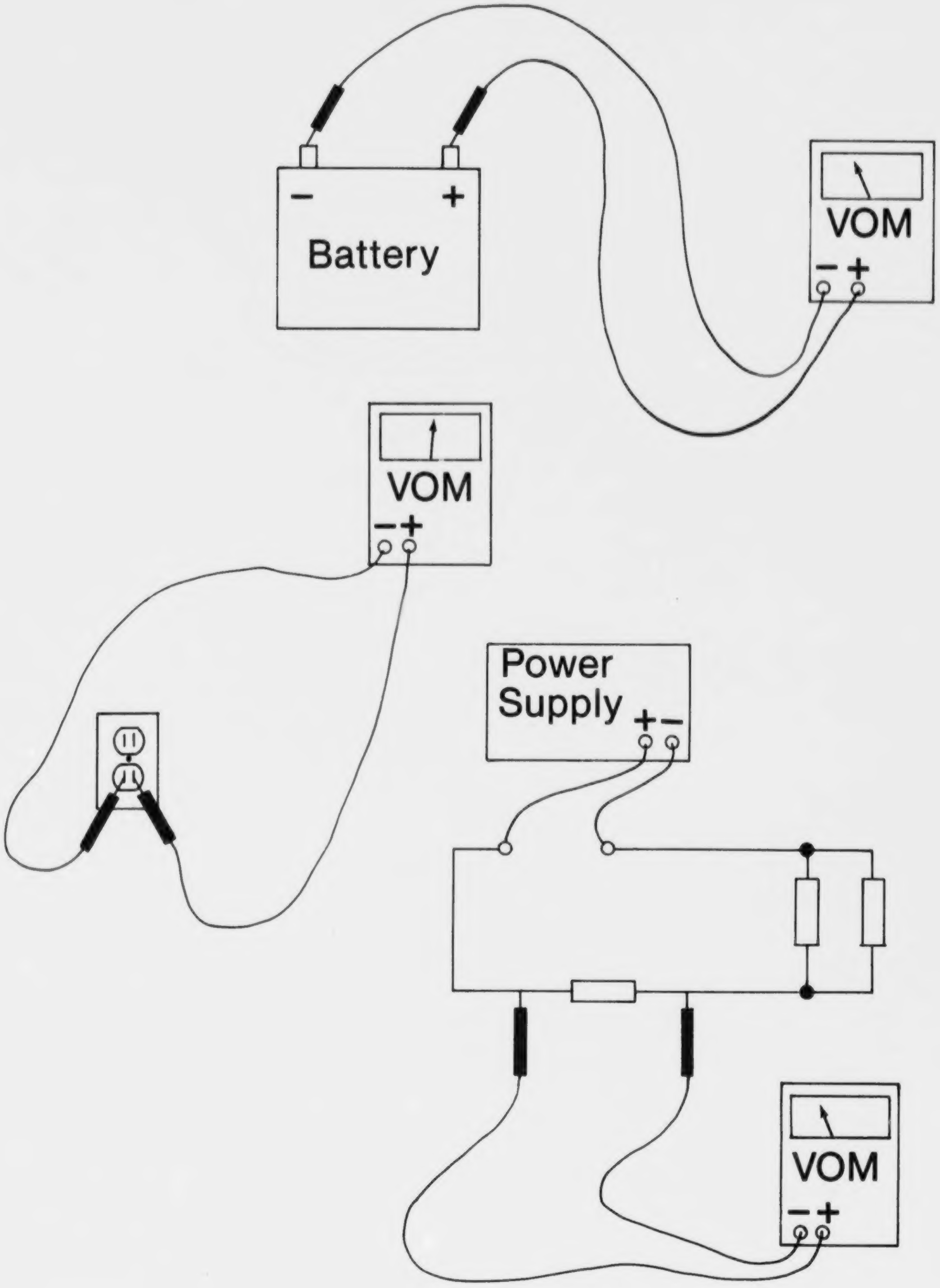
Analog Multimeter


Ohms Scale
DC Scale
AC Scale
2.5 VAC Scale
DB Scale
Pointer
Meter Zero Adjust
OHMS
OHMS
DC
AC
DC
AC
2.5 VAC Only
DB
Simpson
-10A
Output
-DC
+DC
AC
500 mA
2.5 V
10 V
50 V
µA 250 V
1000 V 5000 V
100 mA
10 mA Amps
1 mA
R × 1
R × 100
R × 10,000
50 µA Zero
+10 A Ohms
AC 5000 V
DC 5000 V
Common
-
+
Ohms Zero Adjust
Function Switch
Test Jack
Range Switch

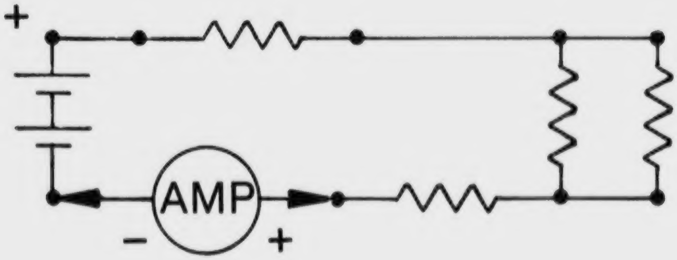
Digital Multimeter


0.00
2000mA
1000 DC
750 AC
MΩ
200mA
200
200k
20mA
20
20k
2mA
2
2k
200μA
200mV
200Ω
DC
AC
A
V
Ω
COMMON
V Ω

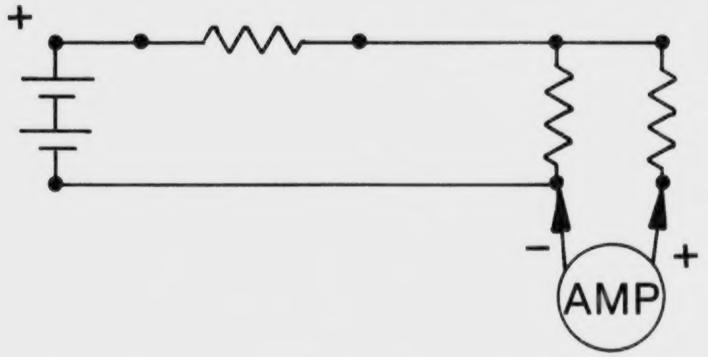
Correct Voltage Measurements


−
+
Battery
VOM
− +
VOM
− +
Power Supply
+ −
VOM
− +

Correct Amperage Measurements

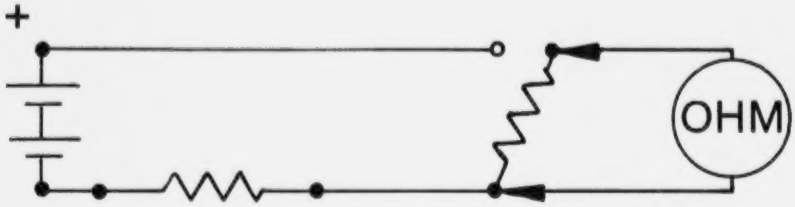


Measuring Amperage in Series Circuits

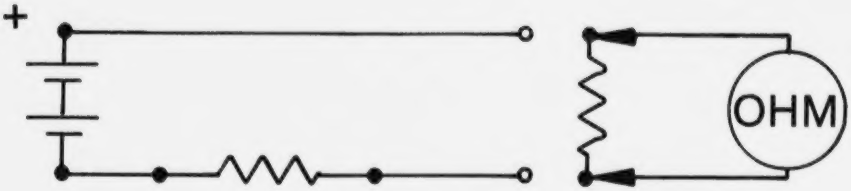


Measuring Amperage in Parallel Circuits

Correct Resistance Measurements

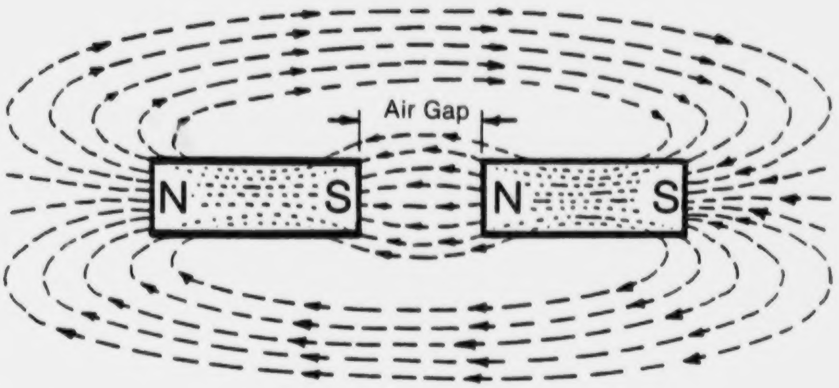


Isolating Component by Removing One Lead

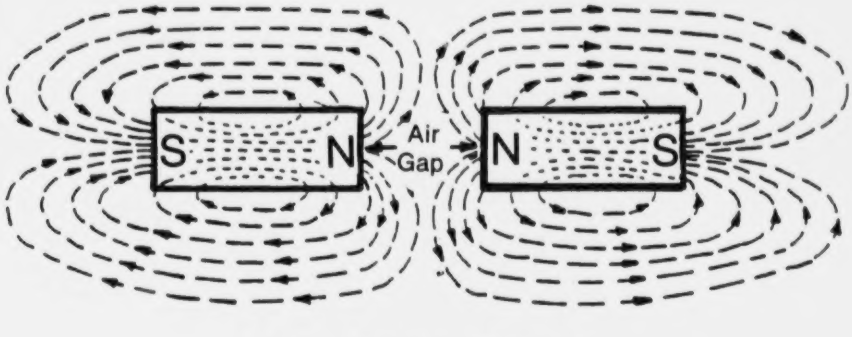


Isolating Component by Removing All Leads

Magnetic Lines of Force

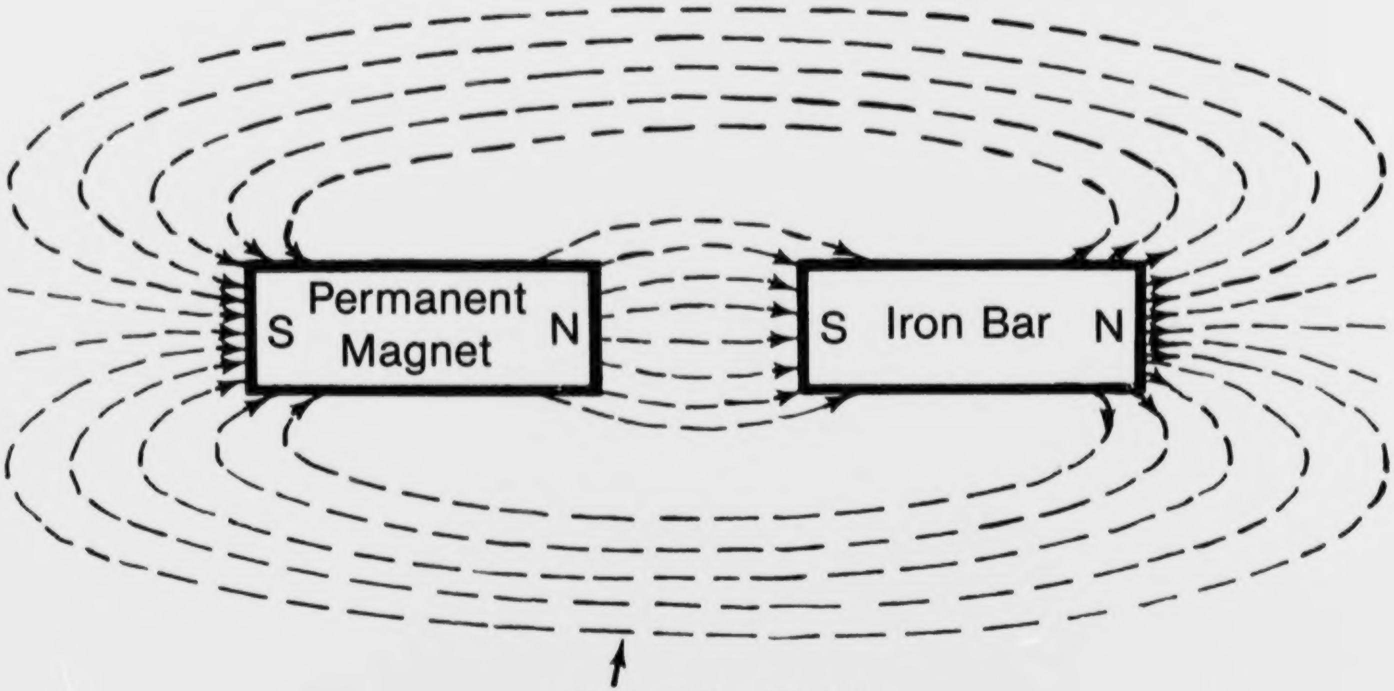

Air Gap
N
S
N
S

Unlike Poles Attract


S
N
Air
Gap
N
S

Like Poles Repel

Induction


S
Permanent
Magnet
N
S
Iron Bar
N
Magnetic Field

Note Opposite North-South Poles

INTRODUCTION TO DC
UNIT II

ASSIGNMENT SHEET #1 — SOLVE PROBLEMS FOR AN UNKNOWN VOLTAGE, AMPERAGE, AND RESISTANCE

Part A

Directions: Apply the appropriate formula from Ohm's law to find the voltage in the following problems.

Example: 2 amps, 60 ohms = ____________ volts

Answer: $E = IR = 2A \times 60\Omega = 120$ volts

Problems:

	Amps	Ohms	Volts
1.	20A	6Ω	________
2.	4A	60Ω	________
3.	9.6A	2.5Ω	________
4.	5A	3Ω	________
5.	75A	0.16Ω	________
6.	2×10^{-3}A	$5 \times 10^{3}\Omega$	________
7.	1×10^{-6}A	$10 \times 10^{3}\Omega$	________
8.	8μA	1MΩ	________
9.	2mA	2KΩ	________
10.	1A	1Ω	________

ASSIGNMENT SHEET #1

Part B

Directions: Apply the appropriate formula to find the amperage in the following problems.

Example: 120 volts, 40 ohms = ____________ amps

Answer: $I = E/R = 120/40 = 3$ A

Problems:

	Volts	Ohms	Amps
1.	240V	12Ω	________
2.	110V	11Ω	________
3.	440V	20Ω	________
4.	120V	30Ω	________
5.	24V	3Ω	________
6.	12V	1Ω	________
7.	5×10^{-6}V	1Ω	________
8.	2×10^{-3}V	$4 \times 10^{-3}\Omega$	________
9.	20 KV	$5 \times 10^{+6}\Omega$	________
10.	1 KV	$0.5 \times 10^{6}\Omega$	________

ASSIGNMENT SHEET #1

Part C

Directions: Apply the appropriate formula to find resistance.

Example: 440 volts, 10 amps = ____________ ohms

Answer: R = E/I = 440V/10A = 44 ohms

Problems:

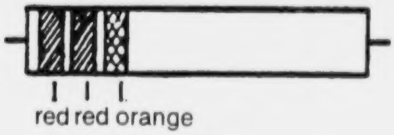
	Volts	Amps	Ohms
1.	240V	4A	
2.	24V	9.6A	
3.	12V	5A	
4.	230V	5A	
5.	24V	8A	
6.	24V	2 mA	
7.	12V	3 μA	
8.	1 KV	5mA	
9.	1×10^{3}V	0.5×10^{-3}A	
10.	2.5×10^{3}V	5×10^{-3}A	

INTRODUCTION TO DC
UNIT II

ASSIGNMENT SHEET #2 — CALCULATE THE RESISTANCE VALUES FROM GIVEN COLOR CODES

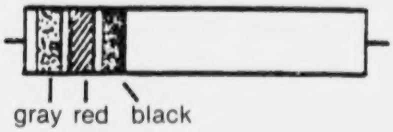
1. Compute the value of the following resistors:

a.


red
red
orange

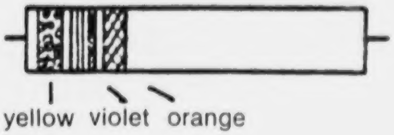
= ______ohms or ______KΩ

b.


gray
red
black

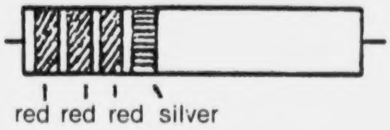
= ______ohms

c.


yellow
violet
orange

= ______ohms or ______KΩ

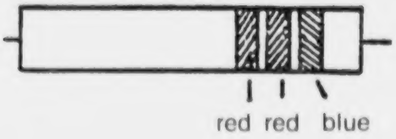
d.


red
red
red
silver

= ______ohms or ______KΩ

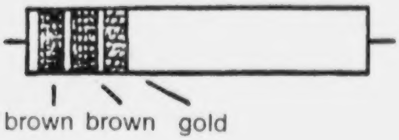
ASSIGNMENT SHEET #2

e.


red
red
blue

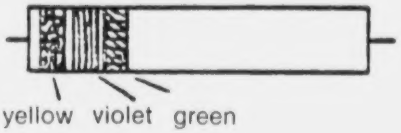
= ______ohms or ______K

f.


brown
brown
gold

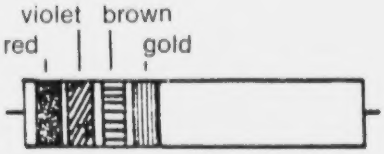
= ______ohms

g.


yellow
violet
green

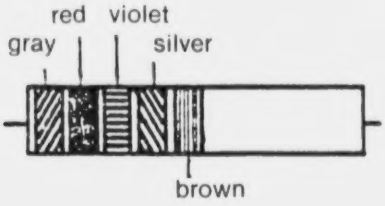
= ______ohms or ______KΩ
or ______M

h.


violet
brown
red
gold

= ______ohms
tolerance ± ______%

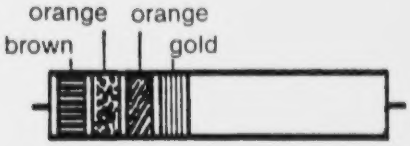
i.


red
violet
gray
silver
brown

= ______ohms or ______MΩ
tolerance ± ______%

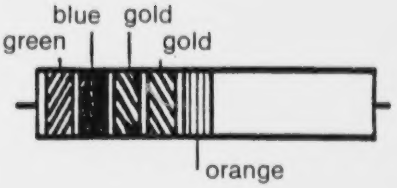
ASSIGNMENT SHEET #2

j.



= ______ohms or ______KΩ
tolerance ± ______%

k.



= ______ohms
tolerance ± ______%

2. The minimum value you would expect resistor "d" to have is ____________ ohms and the maximum value you would expect is ____________ ohms (assuming that it is within tolerance).

3. Refer to the resistors above and answer the following questions.

   a. If the circuit voltage is constant, which resistor would pass the greatest current?

      ____

   b. If the circuit voltage is constant, which resistor would pass the least current?

      ____

   c. What is the largest value resistor "g" can have and still be within tolerance?

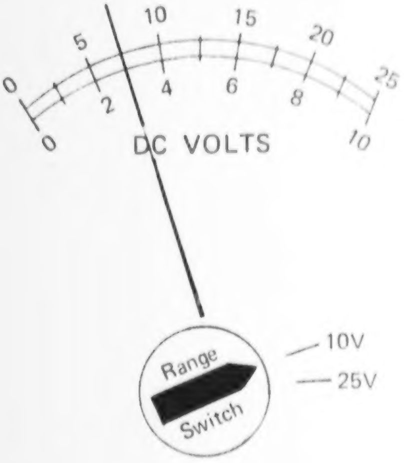
      ____

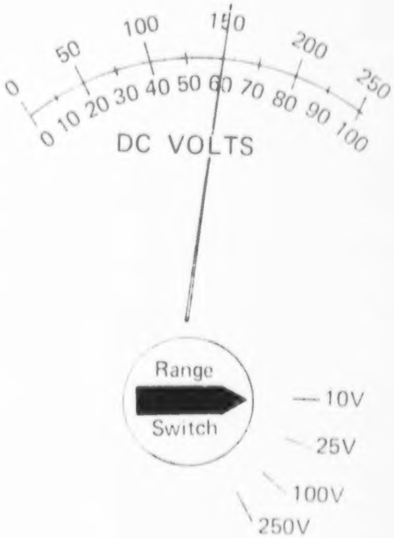
4. The fifth color band in resistors "i" and "k" represents resistor ____________

INTRODUCTION TO DC
UNIT II

ASSIGNMENT SHEET #3 — READ ANALOG VOLTMETER SCALES

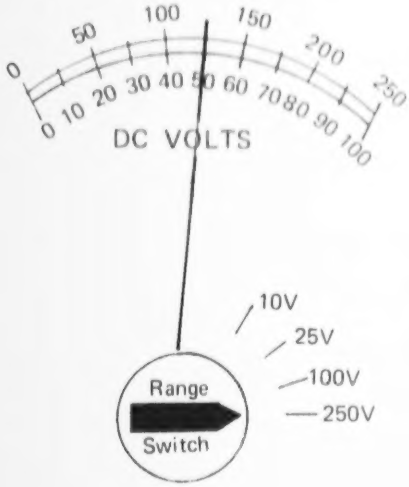
Directions: Write down the voltage reading indicated by the scales.

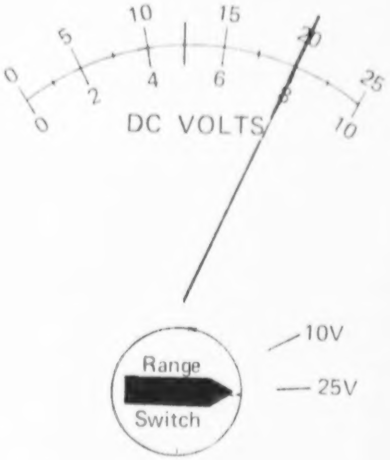

0 5 10 15 20 25
0 2 4 6 8 10
DC VOLTS
Range
Switch
10V
25V


0 50 100 150 200 250
0 10 20 30 40 50 60 70 80 90 100
DC VOLTS
Range
Switch
10V
25V
100V
250V

1. ______________________

2. ______________________


0 50 100 150 200 250
0 10 20 30 40 50 60 70 80 90 100
DC VOLTS
Range
Switch
10V
25V
100V
250V


0 5 10 15 20 25
0 2 4 6 8 10
DC VOLTS
Range
Switch
10V
25V

3. ______________________

4. ______________________

INTRODUCTION TO DC
UNIT II

ASSIGNMENT SHEET #4 — CONVERT AMPERES TO MILLIAMPS AND MICROAMPS

1. Convert the following amps to milliamps.

   a. 1 A = ______ mA
   b. 2 A = ______ mA
   c. 3 A = ______ mA
   d. 3654A = ______ mA
   e. .0214A = ______ mA
   f. .0036A = ______ mA

2. Convert the following A to microamps.

   a. 1 A = ______ μA
   b. 2 A = ______ μA
   c. 3 A = ______ μA
   d. 2.5A = ______ μA
   e. .00037A = ______ μA
   f. .0000028A = ______ μA

3. Convert the following mA to amps.

   a. 4,000 mA = ______ A
   b. 5,000 mA = ______ A
   c. 6,000 mA = ______ A
   d. 25.7mA = ______ A
   e. .0293mA = ______ A
   f. 263.5mA = ______ A

4. Convert the following microamps to amps.

   a. 3,500 μA = ______ A
   b. 4,500 μA = ______ A
   c. 5,500 μA = ______ A
   d. 2,360,000 μA = ______ A
   e. .003μA = ______ A
   f. 3.9μA = ______ A

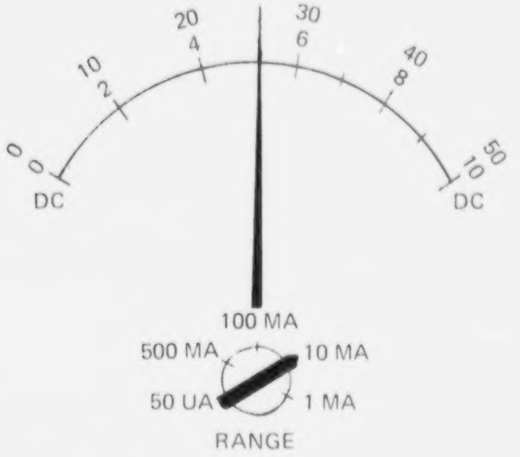
5. Convert as indicated.

   a. .35mA = ______ μA
   b. 635μA = ______ mA
   c. 2.5A = ______ mA
   d. .0035A = ______ μA
   e. 2.45mA = ______ A
   f. 2.93μA = ______ A

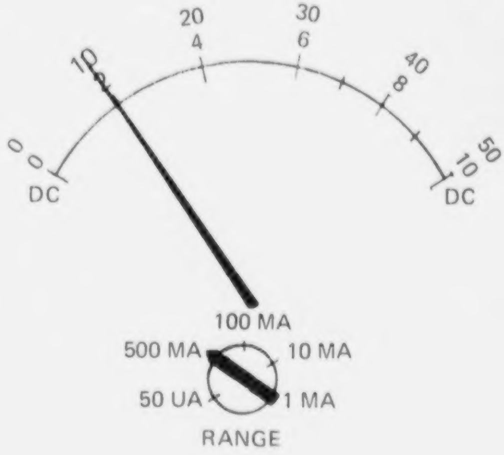
INTRODUCTION TO DC
UNIT II

ASSIGNMENT SHEET #5 — READ ANALOG AMMETER INDICATIONS

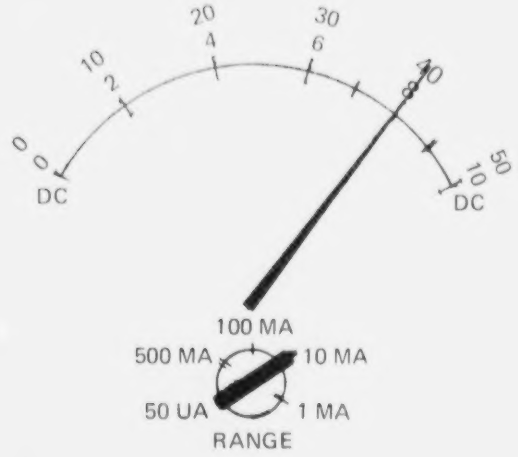
Directions: Write down the current reading for each of the ammeter indications.


0
0
10
2
20
4
30
6
40
8
50
10
DC
DC
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

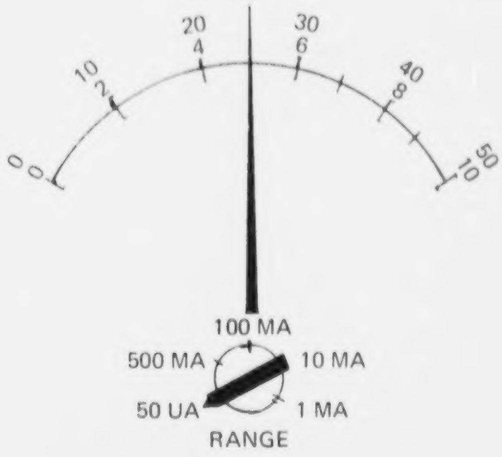
1. ______________________


0
0
10
2
20
4
30
6
40
8
50
10
DC
DC
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

2. ______________________


0
0
10
2
20
4
30
6
40
8
50
10
DC
DC
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

3. ______________________


0
0
10
2
20
4
30
6
40
8
50
10
100 MA
500 MA
10 MA
50 UA
1 MA
RANGE

4. ______________________

INTRODUCTION TO DC
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

Part A

1. 120V
2. 240V
3. 24V
4. 15V
5. 12V
6. 10V
7. 0.01 or 10^{-2}V
8. 8V
9. 4V
10. 1V

Part B

1. 20A
2. 10A
3. 22A
4. 4A
5. 8A
6. 12A
7. 5×10^{-6} or 0.000005 or 5 μA
8. 500×10^{-3} or 0.5 or 5mA
9. 4×10^{-3} or .004 4mA
10. 2×10^{-3} or 0.002 or 2mA

Part C

1. 60 Ω
2. 2.5 Ω
3. 2.4 Ω
4. 46 Ω
5. 3 Ω
6. 12K or 12,000 Ω
7. 4M or 4,000,000 Ω
8. 200K or 200,000 Ω
9. 2×10^{6} or 2,000,000 Ω
10. 500K or 500,000 Ω

Assignment Sheet #2

1. a. 22,000 ohms or 22 K Ω
   b. 82 ohms
   c. 47,000 ohms or 47 K Ω

ANSWERS TO ASSIGNMENT SHEETS

  d. 2200 ohms or 2.2 K Ω

  e. 6200 ohms or 6.2 K Ω

  f. 1.1 ohms

  g. 4,700,000 ohms or 4700 K Ω or 4.7 M Ω

  h. 270 ohms, tolerance ± 5%

  i. 8200000 ohms or 8.2 M Ω tolerance ± 1%

  j. 13,000 ohms or 13 K Ω, tolerance ± 5%

  k. 5.6 ohms, tolerance 5%

2. 1980 ohms minimum (2200 — 220) ohms maximum (2200 ± 10%)

3. a. f

   b. g

   c. 5.64 megohms (4.7 megohms ± 20% = 4.7 + .94 = 5.64 megohms)

4. Reliability

Assignment Sheet #3

1. 3V

2. 6V

3. 125V

4. 20V

Assignment Sheet #4

1. a. 1,000
   b. 2,000
   c. 3,000
   d. 3,654,000
   e. 21.4
   f. 3.6

2. a. 1,000,000
   b. 2,000,000
   c. 3,000,000
   d. 2,500,000
   e. 370
   f. 2.8

3. a. 4
   b. 5
   c. 6
   d. .0257
   e. .0000293
   f. .2635

ANSWERS TO ASSIGNMENT SHEETS

4. a. .0035
   b. .0045
   c. .0055
   d. 2.36
   e. .000000003
   f. .0000039

5. a. 350
   b. .635
   c. 2500
   d. 3500
   e. .00245
   f. .00000293

Assignment Sheet #5

1. 5 mA

2. 100 mA

3. 8 mA

4. 25 μA

INTRODUCTION TO DC
UNIT II

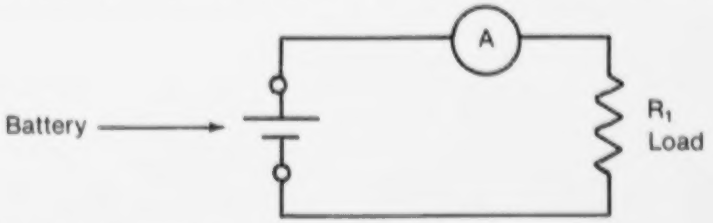
JOB SHEET #1 — MEASURE AND COMPARE CURRENT IN A CIRCUIT AT TWO DIFFERENT VOLTAGE LEVELS

A. Equipment and materials needed

1. DC ammeter (or multimeter)
2. Battery
3. Load (lamp or other resistance)

B. Procedure

1. Connect the circuit as shown below; set DC power source at 1.5 vdc.



2. Calculate and record the current in the circuit.____________________
3. Measure and record the current in the circuit amperage. ____________
4. Increase power source to 3 vdc.
5. Calculate and record the current in the circuit.____________________
6. Measure and record the current.____________
7. Compare current measurements to calculated values, and current measurements at the different voltage settings.

   (NOTE: the following questions may be used for discussion:

   Were the calculated values equal to the measured current?______________

   Is there more current at 1.5 vdc or at 3 vdc power source?______________

   With the same load, what happens to the current in a circuit when you change the voltage applied to the circuit?______________________________

   ____

   What happens if the polarity of the power source is reversed?

   If a lamp was used as the load, did (or would) the lamp glow brighter when the voltage was increased? Why?)

8. Return equipment and materials to their proper storage area.

INTRODUCTION TO DC
UNIT II

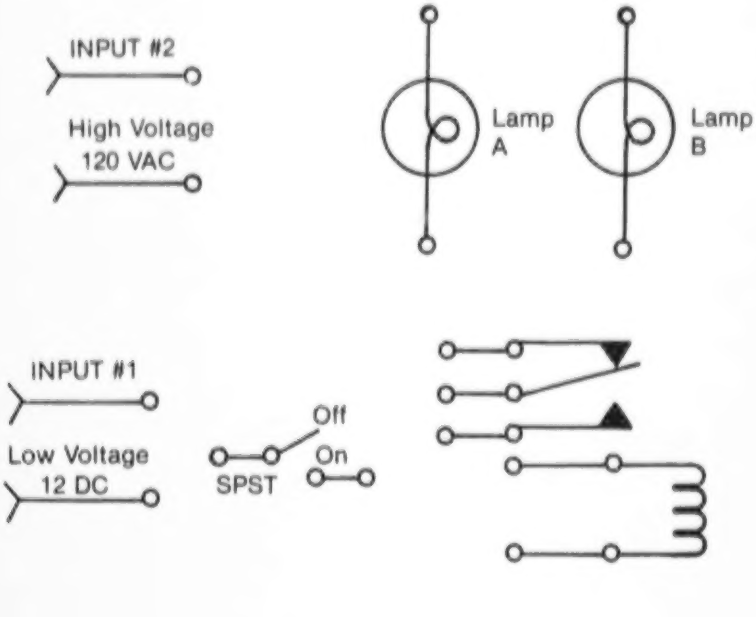
JOB SHEET #2 — WIRE A FUNCTIONAL RELAY CIRCUIT

A. Equipment and materials needed

1. Low voltage DPST relay
2. SPST switch
3. 120 VAC power supply
4. 12 VDC power supply
5. Two 120 VAC lamps
6. Two lamp sockets
7. Test leads

B. Procedure

1. Complete the figure below to satisfy the following conditions.
   a. Lamp A "on" and Lamp B "off" with the switch in the "off" position
   b. Lamp A "off" and Lamp B "on" with the switch in the "on" position


INPUT #2
High Voltage
120 VAC
Lamp A
Lamp B
INPUT #1
Low Voltage
12 DC
Off
On
SPST

JOB SHEET #2

2. Wire the circuit, but do not connect to the 120 VAC source.

3. With the 12V power supply disconnected, adjust the power supply output to match the specified relay voltage.

   (NOTE: Have the instructor inspect the circuit.)

4. Connect the relay coil to the low voltage power supply, and test the relay for proper operation.

5. Connect the circuit to 120 VAC.

   (NOTE: Have the instructor inspect the circuit.)

6. Test for proper operation in accordance with Step 1.

7. Check your results with the instructor.

8. Return equipment and materials to their proper storage area.

INTRODUCTION TO DC
UNIT II

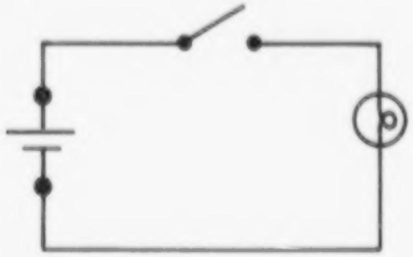
JOB SHEET #3 — MEASURE THE VOLTAGE DROP IN A DC CIRCUIT

A. Tools and equipment needed

1. Voltmeter
2. Battery
3. Lamp or load
4. Switch

B. Procedure

1. Connect the circuit as shown below.



2. Close the switch.
3. Connect the voltmeter **across** the power supply and adjust for 1.5 volts.
4. Read and record the voltmeter indication. ____________
5. Connect the voltmeter **across** the lamp or load.
6. Read and record the voltmeter indication. ____________
7. With the switch still closed, measure and record the voltage across the switch. ____________
8. With the voltmeter still connected to the switch, open the switch.

JOB SHEET #3

9. Read and record the voltmeter indication with the switch open. ____________

(NOTE: Discuss the following in class:

a. The measurement across the load and across the source

b. The voltmeter reading across the closed switch

c. The difference of potential across the load and whether or not the voltage drop occurs across the load or the wire

d. The voltage reading across the open switch.)

10. Return equipment and materials to their proper storage area.

INTRODUCTION TO DC
UNIT II

JOB SHEET #4 — DEMONSTRATE THAT MAGNETIC POLES CAN ATTRACT AND REPEL

A. Equipment and materials needed

1. Two magnets
2. Piece of flat glass (approximately 8" × 10")

   (NOTE: Clear lucite can be used.)
3. Small piece of iron
4. Small piece of brass
5. Shaker of iron filings

B. Procedure

1. Place one magnet on a smooth surface.
2. Bring the north pole of the other magnet close to the north pole of the first one.
3. Describe the action of the magnets: ______________________________

   ____
4. Repeat steps 1 and 2, but bring the north pole of one magnet close to the south pole of the other.

   Describe the action of the magnets: ______________________________

   ____
5. Place the magnets under the glass with *unlike* poles opposite, but not touching, each other.
6. Sprinkle iron filing over the glass and sketch the resulting pattern.
7. Lift the glass and replace the iron filings into the shaker.
8. Place the magnets under the glass with *like* poles opposite, but not touching, each other.
9. Sprinkle iron filings over the glass and sketch the resulting pattern.

   (CAUTION: Wash hands thoroughly to remove iron filings. Do not rub eyes.)

JOB SHEET #4

10. Replace the filings into the shaker.

11. Place one magnet under the glass.

12. On one end of the glass, place the small piece of iron close to the pole of the magnet but not directly over the pole.

13. On the other end in a similar position, place the small piece of brass close to the other pole of the magnet.

14. Sprinkle iron filings on the glass, brass, and iron pieces.

15. Sketch the resulting pattern.

    (NOTE: The following questions may be used for discussion:

    a. Explain the reactions of the magnets in Steps 1, 2, and 4.

    b. Explain how the sketches of like poles and of unlike poles show that there are forces of repulsion and attraction.

    c. What happened to the lines of force as they passed through the small piece of iron? What happened as they passed through the small piece of brass? Do the lines of force also pass through the glass? Explain your sketch made in Step 15.)

16. Return equipment and materials to their proper storage area.

INTRODUCTION TO DC
UNIT II

JOB SHEET #5 — CONSTRUCT A SIMPLE ELECTROMAGNET AND CHECK ITS OPERATION

A. Equipment and materials needed

1. 1.5-volt battery

   (CAUTION: Use no more than 1.5 volts.)

2. 4 feet hook-up wire (insulated)
3. ¼" iron bolt, 3" long
4. Compass
5. Paper clips

B. Procedure

1. Start at one end of the hook-up wire and wrap all of the wire around the bolt, leaving approximately 8 inches on both ends so you can hook your coil to the battery.
2. Before connecting the coil to the battery, check to see that the iron bolt is not a magnet.

   (NOTE: Do this by bringing the compass within 4 inches of each end of the bolt and observe little or no change in the compass needle.)

3. Connect the coil to the battery.
4. Bring the compass within 4 inches of the bolt ends and observe the needle indications for north and south poles.
5. See if the bolt will pick up the paper clips.

   (NOTE: Try both ends of the bolt.)

6. Disconnect the coil from the battery.
7. Carefully remove the bolt trying to keep the coil in its same shape.
8. Reconnect the coil to the battery.
9. Check for polarity and magnetism with your compass by bringing it close to the coil ends.

JOB SHEET #5

10. See if the coil will attract a paper clip.

    (NOTE: Try both ends of the coil.)

11. Disconnect the battery.

    (NOTE: The following questions may be used for discussion:

    a. Is the left-hand rule for coils confirmed by your observations in Step 3?

    b. Explain why both ends of the electromagnet with the bolt in position will pick up the paper clips.

    c. Why was the coil weaker without the bolt? Explain why the polarity observed with the compass was the same with or without the bolt.)

12. Return equipment and materials to their proper storage area.

INTRODUCTION TO DC
UNIT II

NAME ____________________

TEST

1. Match the terms on the right with their correct definitions.

(NOTE: Answers to questions a.-o. appear on this page.)

______a. Electrical force or pressure that causes the flow of electrical current (electrons)

______b. The unit of measurement of electromotive force

______c. Difference in voltage measured across a component in a circuit

______d. An abnormal connection of relatively low resistance between two points of differing potential in a circuit

______e. Total voltage supplied to a circuit; also referred to as supply voltage or source voltage

______f. One (1) divided by that number

______g. Changeable or capable of being changed

______h. A specified element or condition which determines the value of circuit variables

______i. The storage of electrical energy

______j. A property of certain materials which exerts a mechanical force on other materials and which can cause induced voltages in conductors when relative movement is present

______k. An object which will attract iron, nickel, or cobalt and will produce an external magnetic field

______l. The area around a magnet through which the lines of force flow

______m. A core of soft iron that is temporarily magnetized by sending current through a coil of wire wound around the core

______n. How near the instrument reading is to the actual value

______o. Basic unit of electric current

1. Static electricity
2. Ampere
3. Short circuit
4. Variable
5. Volt
6. Magnetic field
7. Parameter
8. Magnetism
9. Electromagnet
10. Accuracy
11. Magnet
12. Applied voltage
13. The reciprocal of a number
14. Voltage
15. Voltage drop

TEST

(NOTE: Answers to questions p.-aa. appear on this page.)

______p. How well an instrument responds to small measurements or small changes in the value being measured

______q. How well the instrument will indicate a small change in the measured value

______r. How far the measurement is from the actual value

______s. Technique of testing and adjusting an instrument by referencing it to another instrument or device of known accuracy and precision

______t. Instrument capable of measuring a "multiple" of values

______u. Total resistance offered by a device; is normally associated with the power source

______v. Common return to earth for AC power lines; chassis ground in electronic equipment is the common return to one side of the internal power supply

______w. Unit of measure for resistance

______x. Establishes the limits of a scale

______y. Opposition to current

______z. The acceptable amount of variation from an indicated value

______aa. The electromotive force developed between two points that moves electric current through a load that is connected across a source

16. Tolerance
17. Ohms
18. Internal resistance
19. Sensitivity
20. Range
21. Resolution
22. Multimeter
23. Potential difference
24. Resistance
25. Error
26. Calibration
27. Ground

TEST

2. Match common parameters used in electronics on the right with their correct symbols and units of measure.

	SYMBOL	UNIT (ACCEPTED ABBREVIATION)	
______a.	I or i	Ampere(A)	1. Frequency
______b.	Q or q	Coulomb (C)	2. Susceptance
______c.	P	Watt (W)	3. Power
______d.	V or v	Volt (V)	4. Capacitance
______e.	E	Volt (V)	5. Impedance
______f.	R	Ohm (Ω)	6. Admittance
______g.	X	Ohm (Ω)	7. Period
______h.	Z	Ohm (Ω)	8. Reactance
______i.	G	Siemens (S)	9. Current
______j.	Y	Siemens (S)	10. Inductance
______k.	B	Siemens (S)	11. Resistance
______l.	C	Farad (F)	12. Voltage drop
______m.	L	Henry (H)	13. Conductance
______n.	f	Hertz (Hz)	14. Charge
______o.	T	Seconds (s)	15. Voltage applied

3. Complete the following chart of numerical decimal equivalents and powers of ten prefixes by correctly filling in the blanks.

UNIT PREFIX	SYMBOL	MULTIPLIER
a. ________	G	1,000,000,000 [10^9]
Mega	b. ________	1,000,000 [10^6]
c. ________	K	1,000 [10^3]
Milli	m	d. ________ [10^{-3}]
e. ________	μ (Greek, μ)	.000001 [10^{-6}]
Nano	f. ________	.000000001 [10^{-9}]
Micromicro or g. ________	$\mu\ \mu$ or ρ	.000000000001 [10^{-12}]

TEST

4. State the number which corresponds to the correct color in the resistor color code.

   a. White — ____________

   b. Green — ____________

   c. Yellow — ____________

   d. Brown — ____________

   e. Gray — ____________

   f. Blue — ____________

   g. Violet — ____________

   h. Orange — ____________

   i. Black — ____________

   j. Red — ____________

   k. Gold — ____________

   l. Silver — ____________

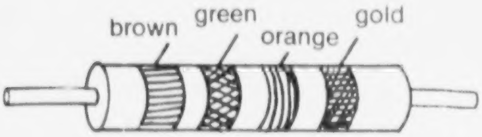
   (NOTE: The following refer to tolerance.)

   m. Silver — ____________

   n. Gold — ____________

   o. No color — ____________

5. Determine resistance using the resistor color code completed in question #4.



TEST

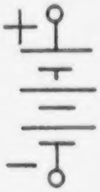
6. Match basic circuit elements on the right with their symbols.

(NOTE: Answers to questions a.-d. appear on this page.)

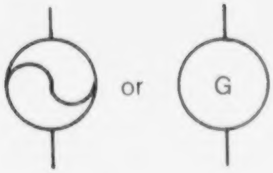
1. Lamp
2. Relay closed
3. Conductor
4. Battery
5. Transformer
6. Resistor
7. Switch open
8. Conductors connected
9. Loudspeaker
10. Generator
11. Conductors not connected
12. Relay open
13. Switch closed

a. Power sources

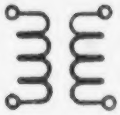
_____1)



_____2)

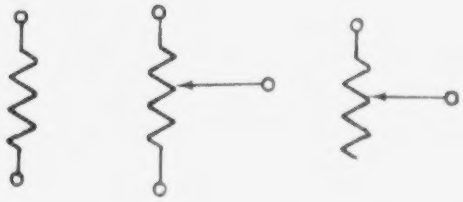


_____3)



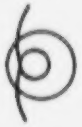
b. Load

_____1)

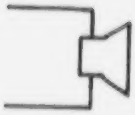


TEST

______2)

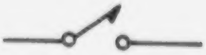


______3)

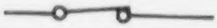


c. Circuit switches

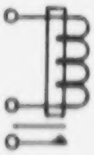
______1)



______2)

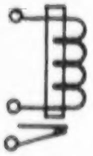


______3)



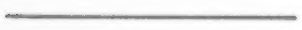
TEST

______4)

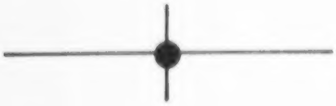


d. Circuit conductors (wires)

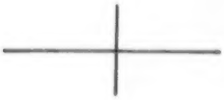
______1)



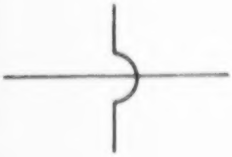
______2)

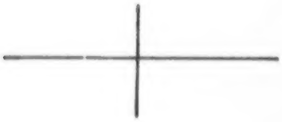


or



______3)





7. List the two types of resistors.

a. ______________________________

b. ______________________________

TEST

8. Complete the following list of meter ranges for analog and digital meters by circling the word which best completes each list of meter ranges.

   a. (**DC, AC**) voltage ranges

      1) Analog — 2.5, 10, 50, 250, 1000, and 5000 volts

      2) Digital — 200mV, 2, 20, 200, and **2000** volts

   b. (**DC, AC**) voltage ranges

      1) Analog — 2.5, 10, 50, 250, 1000, and 5000 volts

      2) Digital — 200mV, 2, 20, 200, and **600** volts

   c. (**DC, AC**) milliamps range

      1) Analog — 1mA, 10mA, 50mA, 100mA, 500mA, and 10A

      2) Digital — 200A, 2mA, 20mA, 2A, and 10A

   d. (**DC, AC**) milliamps range

      1) Analog — 1mA, 10mA, 50mA, 100mA, 500mA, and 10A

      2) Digital — 200A, 2mA, 20mA, 2A, and 10A

   e. (**Milliohm, Ohm**) ranges

      1) Analog — ×1, ×100, ×1000, and ×10,000

      2) Digital — 0-200, 0-2K, 0-20K, 0-200K, 0-2000K, and 0-20M

9. Match types of meter scales on the right with their correct uses.

   ______a. Used to do nonlinear indications below 2 volts

   ______b. Used for power level measurements

   ______c. Used for resistance measurements. Zero readings will always indicate a short. Readings at the left most side of the scale indicate infinite resistance or an open.

   ______d. Used for direct current voltage measurements

   ______e. Used for alternating current voltage readings

   1. DC scale
   2. DB scale
   3. Ohm's scale
   4. 2.5 volt AC scale
   5. AC scale

TEST

10. Arrange in order the general steps used in preparing a multimeter for operation by indicating the first step as 1, the second step as 2, and so on for each step.

_____a. Connect test leads to proper test jacks.

_____b. Make necessary meter adjustments

_____c. Select the range or anticipated limits of measurement required.

_____d. Select function to be measured.

11. Distinguish between a voltmeter and an ammeter by placing a "V" next to the characteristics of a voltmeter.

_____a. Low resistance to current flow

_____b. Range can be increased by adding a series resistance

_____c. Measures across the circuit or device

_____d. Range can be increased by adding a parallel (shunt) resistance

_____e. High resistance to current flow

_____f. Measures in series with the circuit or device

12. Arrange in order the procedures for measuring voltage by indicating the first step as 1, the second steps as 2, and so on for each procedure.

_____a. Set meter on lowest scale at which it will register.

_____b. Turn off meter.

_____c. Observing polarity, connect meter leads to meter.

__4__d. Observing polarity, connect meter leads to circuit to be tested.

_____e. Position meter to correct function.

_____f. Read correct voltage.

__3__g. Determine correct range and scale.

_____h. Disconnect meter leads.

TEST

13. Select from the following list procedures for measuring amperage by placing an "X" in the blank preceding each correct procedure.

_____a. Turn on power to circuit under test.

_____b. Position meter to correct scale.

_____c. Observing polarity, connect test leads to circuit.

_____d. Connect meter in circuit to be tested, observing polarity and connecting in series with the circuit.

_____e. Observe meter reading.

_____f. Position range switch to correct scale for most accurate reading.

14. Complete the following list of procedures for measuring resistance by inserting the word(s) which best complete(s) each statement.

a. Turn ____________ power to circuit under test.

b. Position meter to the correct function position.

c. Position meter range switch to one of the ____________ scales.

d. Insert meter leads in correct meter ____________, observing polarity.

e. ____________ component to be checked.

f. Connect meter across component to be measured.

g. Determine correct meter position closest to ____________ or toward zero.

h. Perform zero ohms adjustment according to manufacturer's manual.

i. Reconnect meter to component.

j. Read meter for ____________value.

k. Remove meter leads.

l. Turn off meter.

m. Reconnect component in circuit.

TEST

15. Select true statements concerning amperage measurement characteristics by placing an "X" in the blanks preceding the true statements.

_____a. All current passes through the ammeter.

_____b. Technique is limited to large measurements.

_____c. Alternating current or direct current can be measured.

16. Complete the following list of voltage measurement characteristics by inserting the word(s) which best complete(s) each statement.

a. Voltmeter probes connect ____________ across terminals.

b. Technique is limited to ____________ AC or DC voltages.

17. State Ohm's law.

____

____

18. List three uses of Ohm's law.

a. ____

b. ____

c. ____

19. Select true statements concerning magnetic properties by placing an "X" in the blanks preceding the true statements.

a. Magnetic lines of force

_____1) Are continuous and form complete loops

_____2) Cross each other

_____3) Cause like poles (north-north, south-south) to attract each other

_____4) Cause unlike poles (north-south, south-north) to repel each other

_____5) Parallel lines going in the same direction repel each other

_____6) Attract other lines going in the same direction

_____7) Exert tension along their lengths, tending to shorten themselves

_____8) Pass through all materials, both magnetic and nonmagnetic

_____9) Tend to enter or leave magnetic material at 60° angles to the surface

_____10) Tend to flow in paths of least opposition

TEST

b. Magnetic field

_____1) Area around magnet through which force lines flow

_____2) Direction of flow is always from south pole to north pole

c. Magnetic flux

_____1) Sum total of magnetic field force lines flowing from north pole to south pole

_____2) Symbol for magnetic flux — Greek letter phi (Φ)

_____3) Unit of flux — Maxwell; two maxwells (Mx) equal one line of force

_____4) Flux density — Number of force lines per given area; symbol is (B)

20. Discuss the use of the left-hand rule for conductors and coils.

a. Left-hand rule for conductors

1) ______________________________

2) ______________________________

b. Left-hand rule for coils

1) ______________________________

2) ______________________________

21. Complete the following list of statements concerning the method and effect of induction by inserting the word(s) which best complete(s) each statement.

a. Method

1) Place iron bar in vicinity of permanent magnet.

2) Do not allow iron bar to touch ____________.

b. Effect

1) Magnetic field lines of force flow through the iron bar.

2) The iron bar becomes ____________.

3) Pole polarity is ____________.

4) The permanent magnet ____________ the iron bar.

TEST

22. Match types of grounds on the right with their correct descriptions.

_____a. Voltage reference point or current return

_____b. A rod or pipe that is buried in the earth

_____c. Connected to a metal chassis or outer cabinet enclosure

1. Chassis ground
2. Earth ground
3. Signal or common ground

23. Match static electricity controls on the right with their correct uses.

_____a. Integrate personnel into grounding system

_____b. Give parallel leakage paths

_____c. Used to ionize the air around an immediate work area where electrostatic sensitive components are used

1. Stool covers, bench tops, and ground cords
2. Wrist straps
3. Air ionizers

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

24. Solve problems for an unknown voltage, amperage, and resistance. (Assignment Sheet #1)

25. Calculate the resistance values from given color codes. (Assignment Sheet #2)

26. Read analog voltmeter scales. (Assignment Sheet #3)

27. Convert amperes to milliamps and microamps. (Assignment Sheet #4)

28. Read analog ammeter indications. (Assignment Sheet #5)

29. Demonstrate the ability to:

    a. Measure and compare current in a circuit at two different voltage levels. (Job Sheet #1)

    b. Wire a functional relay circuit. (Job Sheet #2)

    c. Measure the voltage drop in a DC circuit. (Job Sheet #3)

    d. Demonstrate that magnetic poles can attract and repel. (Job Sheet #4)

    e. Construct a simple electromagnet and check its operation. (Job Sheet #5)

INTRODUCTION TO DC
UNIT II

ANSWERS TO TEST

1. a. 14
   b. 5
   c. 15
   d. 3
   e. 12
   f. 13
   g. 4
   h. 7
   i. 1
   j. 8
   k. 11
   l. 6
   m. 9
   n. 10
   o. 2
   p. 19
   q. 21
   r. 25
   s. 26
   t. 22
   u. 18
   v. 27
   w. 17
   x. 20
   y. 24
   z. 16
   aa. 23

2. a. 9
   b. 14
   c. 3
   d. 12
   e. 15
   f. 11
   g. 8
   h. 5
   i. 13
   j. 6
   k. 2
   l. 4
   m. 10
   n. 1
   o. 7

3. a. Giga
   b. M
   c. Kilo
   d. .001
   e. Micro
   f. η
   g. Pico

4. a. 9
   b. 5
   c. 4
   d. 1
   e. 8
   f. 6
   g. 7
   h. 3
   i. 0
   j. 2
   k. .1
   l. .01
   m. ± 10%
   n. ± 5%
   o. ± 20%

5. 15K

6. a. Power sources
      1) 4
      2) 10
      3) 5

ANSWERS TO TEST

b. Load
  1) 6
  2) 1
  3) 9
c. Circuit switches
  1) 7
  2) 13
  3) 12
  4) 2
d. Circuit conductors
  1) 3
  2) 8
  3) 11

7. a. Fixed
   b. Adjustable

8. a. DC voltage ranges
   b. AC voltage ranges
   c. AC milliamps range
   d. DC milliamps range
   e. Ohm ranges

9. a. 4
   b. 2
   c. 3
   d. 1
   e. 5

10. a. 3
    b. 4
    c. 2
    d. 1

11. b, c, e

12. a. 5
    b. 8
    c. 2
    d. 4
    e. 1
    f. 6
    g. 3
    h. 7

13. b, d, e, f

14. a. Off
    c. Resistance
    d. Jacks
    e. Isolate
    g. Center scale
    j. Ohmic

ANSWERS TO TEST

15. a, c

16. a. Directly
    b. Moderate

17. The current (amperes) in an electric circuit equals the electromotive force or potential (volts) divided by the resistance (ohms)

18. a. Calculating circuit resistance
    b. Calculating circuit amperage
    c. Calculating circuit voltage

19. a. 1, 5, 7, 8, 10
    b. 1
    c. 1, 2, 4

20. a. Left-hand rule for conductors
        1) Grasp conductor with left hand as shown, making sure thumb is pointing in direction of electron flow in the conductor.
        2) Direction of magnetic field flow is in the direction of the four fingers, from large knuckles toward fingertips.
    b. Left-hand rule for coils
        1) Grasp the coil with left hand as shown below so that the four fingers (from knuckles to fingertips) point in direction of electron flow through the coiled conductor.
        2) The thumb now points toward the north pole of the electromagnet.

21. a. 2) Magnet
    b. 2) Electromagnetized
       3) Reversed
       4) Attracts

22. a. 3
    b. 2
    c. 1

23. a. 2
    b. 1
    c. 3

24.-28. Evaluated to the satisfaction of the instructor

29. Performance skills evaluated to the satisfaction of the instructor

CIRCUITRY
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to apply theoretical knowledge of circuitry to determine unknown values in circuits, and calculate current, voltage, resistance, and power in circuits. The student should also be able to analyze a series and series-parallel circuit. Competencies will be demonstrated by correctly performing the procedures outlined in the assignment and job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to circuitry with their correct definitions.
2. Select true statements concerning voltage in a series circuit.
3. Complete a list of statements concerning resistance in a series circuit.
4. Select true statements concerning current in a series circuit.
5. Select true statements concerning voltage in a parallel circuit.
6. Complete a list of statements concerning resistances in parallel.
7. Select true statements concerning current in a parallel circuit.
8. Complete a list of statements concerning voltage in a series-parallel circuit.
9. Arrange in order steps to simplify resistance in a series-parallel circuit.
10. Select true statements concerning current in a series-parallel circuit.
11. Complete a list of statements concerning characteristics of electrical power.
12. Select true statements concerning functions of a voltage divider.
13. Determine total voltage in a series circuit. (Assignment Sheet #1)

OBJECTIVE SHEET

14. Determine voltage drops across resistances. (Assignment Sheet #2)
15. Determine the total resistance in a series circuit. (Assignment Sheet #3)
16. Determine current in a series circuit. (Assignment Sheet #4)
17. Determine unknown circuit values. (Assignment Sheet #5)
18. Determine unknown values in a resistive series circuit. (Assignment Sheet #6)
19. Compute the power dissipated in a resistive series circuit. (Assignment Sheet #7)
20. Calculate current and voltage in parallel circuits. (Assignment Sheet #8)
21. Calculate resistance in parallel circuits. (Assignment Sheet #9)
22. Calculate power in parallel circuits. (Assignment Sheet #10)
23. Calculate various values in parallel circuits. (Assignment Sheet #11)
24. Trace current flow in series-parallel circuits. (Assignment Sheet #12)
25. Perform exercises in circuit reduction. (Assignment Sheet #13)
26. Solve for total resistance. (Assignment Sheet #14)
27. Solve for total current. (Assignment Sheet #15)
28. Solve for total voltage. (Assignment Sheet #16)
29. Solve for branch voltages and currents in series-parallel circuits. (Assignment Sheet #17)
30. Solve for multiple values of voltages and current. (Assignment Sheet #18)
31. Answer questions regarding opens and shorts in series-parallel circuits. (Assignment Sheet #19)
32. Answer questions about grounds and voltage polarity. (Assignment Sheet #20)
33. Analyze no-load and load circuits. (Assignment Sheet #21)
34. Demonstrate the ability to:
    a. Verify Ohm's law. (Job Sheet #1)
    b. Analyze a series circuit. (Job Sheet #2)
    c. Measure voltage, current, and resistance in a parallel circuit. (Job Sheet #3)
    d. Analyze a series-parallel circuit. (Job Sheet #4)
    e. Construct a voltage divider and analyze its function. (Job Sheet #5)

CIRCUITRY
UNIT III

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Construct a parallel circuit with an ammeter and variable resistor in each branch.
2. Demonstrate the current dividing effect of the parallel circuit.
3. Demonstrate voltage dividers by showing how voltage and current are affected by varying the circuit components.
4. Demonstrate the effects of excess power on electrical components.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

   1. TM 1 — Simple Series Circuit
   2. TM 2 — Combined Series Circuit
   3. TM 3 — Resistance in Parallel Circuits
   4. TM 4 — The Reciprocal Resistance Method
   5. TM 5 — Finding the Total Resistance in Parallel Circuits
   6. TM 6 — Current Flow in a Parallel Circuit
   7. TM 7 — Finding Current in a Parallel Circuit
   8. TM 8 — Steps to Simplify a Series-Parallel Circuit
   9. TM 9 — Series-Parallel Circuit and Equivalent Circuit
   10. TM 10 — Circuit Reduction (Step A)
   11. TM 11 — Circuit Reduction (Step B)
   12. TM 12 — Power

E. Assignment sheets

   1. Assignment Sheet #1 — Determine Total Voltage in a Series Circuit
   2. Assignment Sheet #2 — Determine Voltage Drops Across Resistances
   3. Assignment Sheet #3 — Determine the Total Resistance in a Series Circuit
   4. Assignment Sheet #4 — Determine Current in a Series Circuit
   5. Assignment Sheet #5 — Determine Unknown Circuit Values
   6. Assignment Sheet #6 — Determine Unknown Values in a Resistive Series Circuit
   7. Assignment Sheet #7 — Compute the Power Dissipated in a Resistive Series Circuit
   8. Assignment Sheet #8 — Calculate Current and Voltage in Parallel Circuits

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

9. Assignment Sheet #9 — Calculate Resistance in Parallel Circuits
10. Assignment Sheet #10 — Calculate Power in Parallel Circuits
11. Assignment Sheet #11 — Calculate Various Values in Parallel Circuits
12. Assignment Sheet #12 — Trace Current Flow in Series-Parallel Circuits
13. Assignment Sheet #13 — Perform Exercises in Circuit Reduction
14. Assignment Sheet #14 — Solve for Total Resistance
15. Assignment Sheet #15 — Solve for Total Current
16. Assignment Sheet #16 — Solve for Total Voltage
17. Assignment Sheet #17 — Solve for Branch Voltages and Currents in Series-Parallel Circuits
18. Assignment Sheet #18 — Solve for Multiple Values of Voltages and Current
19. Assignment Sheet #19 — Answer Questions Regarding Opens and Shorts in Series-Parallel Circuits
20. Assignment Sheet #20 — Answer Questions About Grounds and Voltage Polarity
21. Assignment Sheet #21 — Analyze No-Load and Load Circuits

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Verify Ohm's Law
2. Job Sheet #2 — Analyze a Series Circuit
3. Job Sheet #3 — Measure Voltage, Current, and Resistance in a Parallel Circuit
4. Job Sheet #4 — Analyze a Series-Parallel Circuit
5. Job Sheet #5 — Construct a Voltage Divider and Analyze its Function

H. Test

I. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

(NOTE: The following is a list of references used in completing this unit.)

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co.

B. Hall, Douglas V. *Microprocessors and Digital Systems.* New York: McGraw-Hill, 1983.

C. Herrich, Clyde N. *Instruments and Measurements for Electronics.* New York: McGraw-Hill, 1972.

D. Horvath, T. *Static Elimination.* Letchworth, England: Research Studies Press, 1982.

E. *New Mexico Vocational Industrial Safety Guide.* Santa Fe, NM: New Mexico State Department of Education.

F. Robertson, L. Paul. *Basic Electronics I (Revised Edition).* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

G. Siebert, Leo N. *Introduction to Industrial Electricity-Electronics.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1981.

CIRCUITRY
UNIT III

INFORMATION SHEET

I. **Terms and definitions**

A. Branch circuit — Circuit originating from a main circuit, often one of many

B. Circuit — A system of conductors through which an electric current is intended to flow

C. Circuit analysis — Applying Ohm's law and other rules to determine the effect of certain parameters on circuit variables

D. Circuit breaker — A device designed to switch open a circuit automatically when a current overload exists; this device may be reset

E. Fuse — An overcurrent protective device with an element that melts and opens the circuit when overheated; this device must be replaced

F. Node — A junction point in a circuit at which current divides into separate branches, or reunites from separate branches

G. Open circuit — A circuit with no available path for current to flow (infinite resistance)

H. Parallel circuit — An electronic circuit which provides more than one path (or branch) for current to flow

I. Power — The rate of doing work

J. Series circuit — A circuit where the same current passes through each component

K. Series-parallel circuit — A circuit that contains some components in series and some in parallel

(NOTE: A series-parallel circuit is also referred to as a complex circuit.)

L. Shunt — Circuit that bypasses another circuit or device, especially a low-resistance bypass for an ammeter circuit

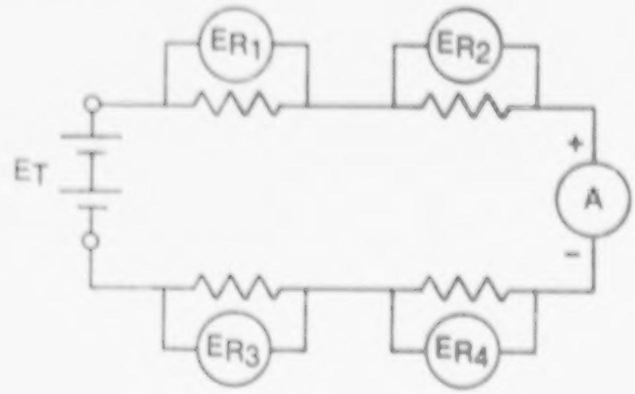
M. Watt — Unit of measure for power

N. Work — Amount of energy used in a specified time

INFORMATION SHEET

II. **Voltage in a series circuit** (Transparencies 1 and 2)

A. The sum of the voltages measured across each resistor will equal the applied voltage.



$E_T = E_{R_1} + E_{R_2} + E_{R_3} + E_{R_4}$

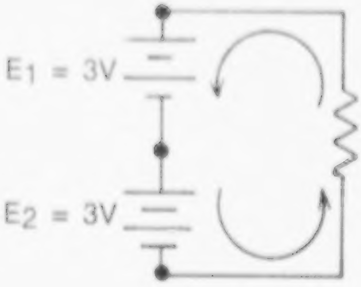
B. The voltage measured across each resistor can be calculated by using Ohm's law when both total current and resistance are known.

Example: If $R_1 = 100\Omega$ and $I_T = 20mA$

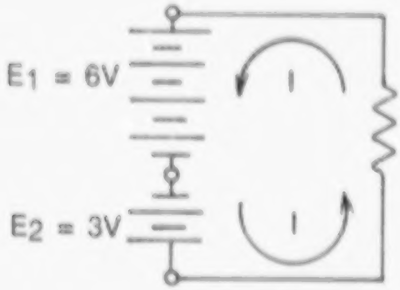
$E_{R_1} = I_T \times R_1 = 20mA \times 100\Omega = 2V.$

C. Voltages added in series can be either series-aiding or series-opposing.

Example:



$E_T = E_1 + E_2 = 6V$
Series-aiding



$E_T = E_1 - E_2 = 3V.$
Series-opposing

INFORMATION SHEET

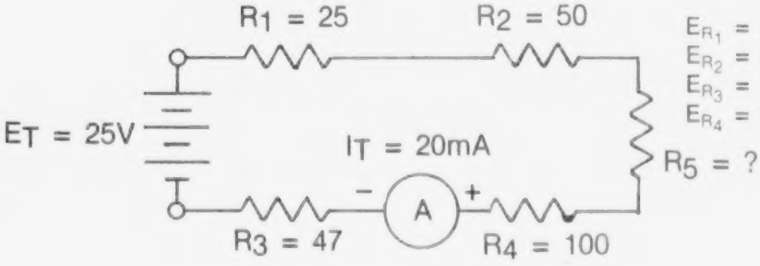
III. Resistance in a series circuit

A. The sum of the resistance (R_T) equals the total resistance.

Example: $R_{TOTAL} = R_1 + R_2 + R_3 + \ldots + R_N$

B. The resistance value of an unknown resistor in series can be calculated by using Ohm's law and Kirchhoff's voltage law.

Example:



$E_{R_1} = 20mA \times 25\Omega = .5V$
$E_{R_2} = 20mA \times 50\Omega = 1V$
$E_{R_3} = 20mA \times 47\Omega = .94V$
$E_{R_4} = 20mA \times 100\Omega = 2V$

$$E_{R_?} = E_T - (E_{R_1} + E_{R_2} + E_{R_3} + E_{R_4}) = 25 - (.5 + 1 + .94 + 2)$$
$$= 20.56V.$$

$$R_? = \frac{E_{R?}}{I_T} = \frac{20.56}{20mA} = 1028\Omega$$

IV. Current in a series circuit

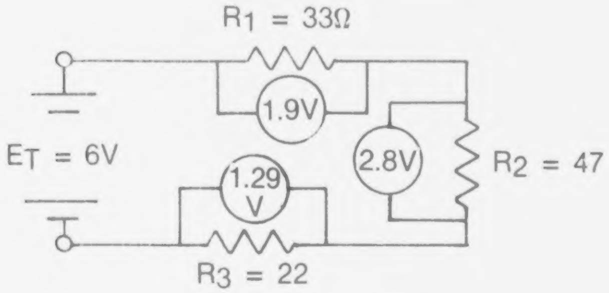
A. The current through each resistor is equal to the total current (I_T). (Transparency 2)

Example: $I_T = I_{R_1} = I_{R_2} = I_{R_3}$

INFORMATION SHEET

B. Total current can be calculated using Ohms law from any voltage drop and resistance value.

Example:



R1 = 33Ω
1.9V
ET = 6V
2.8V
R2 = 47
1.29 V
R3 = 22

$$R_T = R_1 + R_2 + R_3 = 33\Omega + 47\Omega + 22\Omega = 102\Omega$$

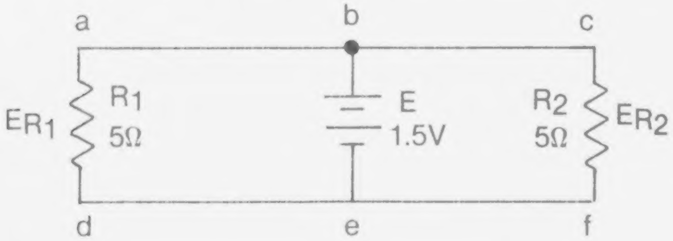
$$I_T = \frac{E_T}{R_T} = \frac{6V}{102\Omega} = .059 \text{ Amps or } 59 \text{ mAmps}$$

$$I_T = \frac{E_{R_1}}{R_1} = \frac{1.9V}{33} = .059 \text{ Amps or } 59 \text{ mAmps}$$

V. Voltage in a parallel circuit

A. The voltage is the same across parallel branches.

Example: In the parallel circuit below, E_{ad} and E_{cf} are of the same (1.5V) because points a, b, and c, and points d, e, and f are exactly the same

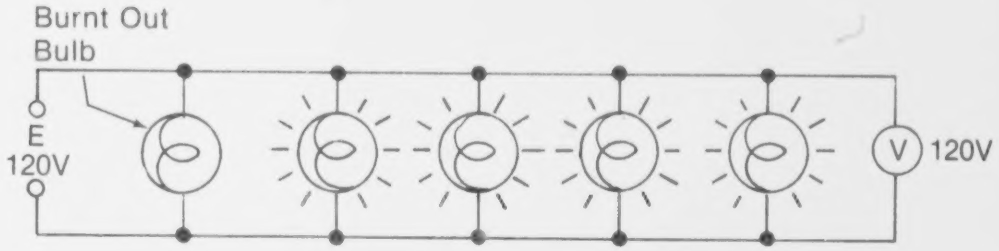


a
b
c
ER1
R1
5Ω
E
1.5V
R2
5Ω
ER2
d
e
f

INFORMATION SHEET

B. Branch elements in a parallel circuit work independently of each other.

(NOTE: If Christmas tree lights are connected in parallel, the whole string does not go out when one bulb burns out. (See diagram below.) This is because the voltage remains across parallel branches even though one branch is open. If the bulbs were connected in series, the whole string of bulbs would go out when any one burned out.)



VI. **Resistances in parallel** (Transparencies 3, 4, and 5)

A. Ohm's law is used to determine total resistance if current is known: $R_T = E/I_T$.

B. If current is not known, the reciprocal resistance formula is used to compute total resistance:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$$

C. Equal branch method is used if resistors of equal value (R) are connected in parallel:

$R_T = R/N$ where N is the total number of equal resistors

Example: If three 30-ohm resistors are connected in parallel, R_T equals 30/3 or 10 ohms

D. Unequal branch method is used when two resistors (R_1 and R_2) of unequal value are connected in parallel:

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

E. Parallel rule — The total resistance of parallel resistors is always less than the resistance of any one branch.

INFORMATION SHEET

VII. **Current in a parallel circuit** (Transparencies 6 and 7)

A. A part of the total circuit current flows through each branch.

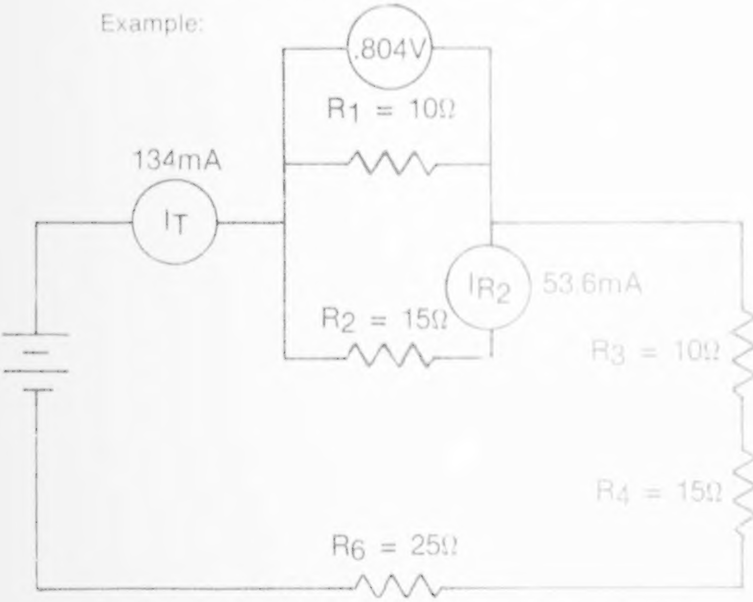
B. The current of each branch equals the voltage divided by the resistance of the branch ($I_1 = E/R_1$).

C. The main line current (I_T) equals the sum of the branch currents ($I_1 + I_2 + I_3 + \ldots$).

VIII. **Voltage in a series-parallel circuit**

A. The voltage drop across any resistance in a series string is equal to the resistance multiplied by the current of that string.

Example:



$$E_{R2} = I_{R2} \times R_2 = .0536\text{A} \times 15\Omega = .804\text{V}$$

B. The total of the voltage drops in a series string equals the voltage across the entire string.

IX. **Steps to simplify resistance in a series-parallel circuit** (Transparencies 8, 9, 10, and 11)

A. Identify series resistors.

B. Identify all parallel groups of resistors.

C. Reduce each parallel group to an equivalent resistance, R_{eq}.

D. Redraw the circuit using a single resistor to represent each equivalent resistance.

E. Combine all equivalent resistance and series resistances to determine total resistance.

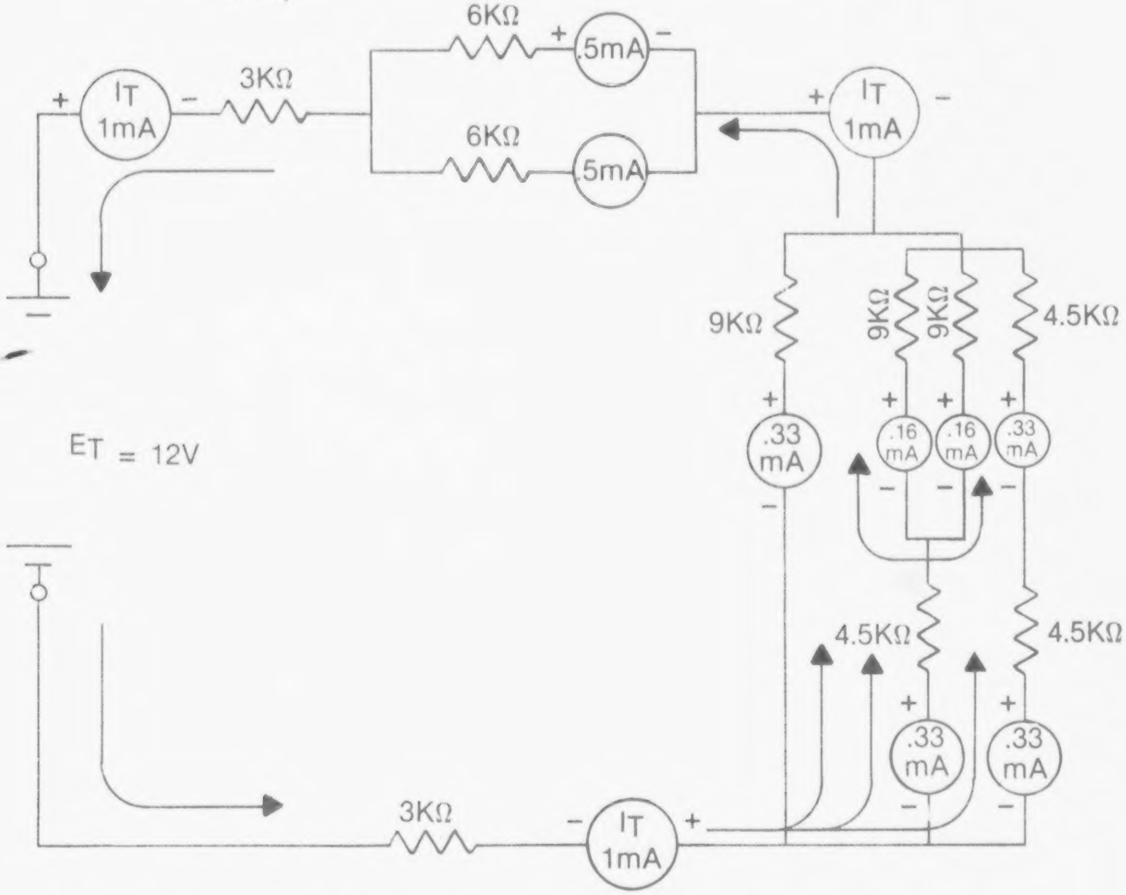
INFORMATION SHEET

X. **Current in a series-parallel circuit**

A. Current in each branch of a series-parallel circuit equals the voltage across the branch divided by the total resistance in the branch.

B. Total line current equals the sum of the currents in each branch.

Example:


6KΩ
.5mA
3KΩ
IT 1mA
6KΩ
.5mA
IT 1mA
9KΩ
9KΩ
9KΩ
4.5KΩ
.33 mA
.16 mA
.16 mA
.33 mA
ET = 12V
4.5KΩ
4.5KΩ
.33 mA
.33 mA
3KΩ
IT 1mA
+
−

XI. **Characteristics of electrical power** (Transparency 12)

A. The fundamental unit of measure for electrical power is the watt (W) and may be measured with an instrument called a wattmeter.

1. Electrical power is the time rate at which a change is moved by voltage.

2. One watt equals the work accomplished in one second by one volt of potential different in moving one coulomb of charge.

(NOTE: 746 watts = 1 horsepower.)

INFORMATION SHEET

B. Power (P) in an electrical circuit may be calculated by using Watt's law, expressed by three basic formulas:

$$P \text{ (in watts)} = E \text{ (volts) } I \text{ (amperes)}$$

$$P \text{ (in watts)} = I^2 \text{ (amperes) } R \text{ (ohms)}$$

$$P \text{ (in watts)} = \frac{E^2 \text{ (volts)}}{R \text{ (ohms)}}$$

C. Power is dissipated in resistance in the form of heat and is made evident by a voltage drop across the resistance.

XII. **Functions of a voltage divider**

A. A voltage divider allows tapping off of different voltages for various applications.

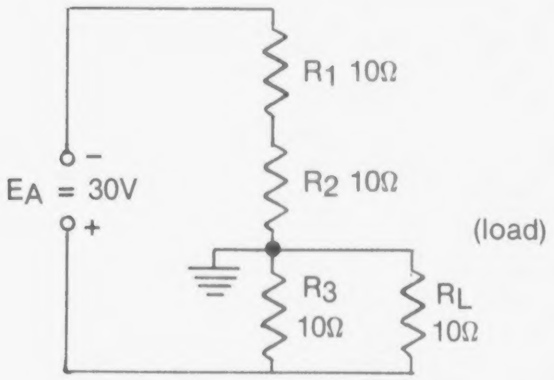
B. Chassis ground is often used as the zero reference point.

C. Tapped voltages may be either positive or negative.

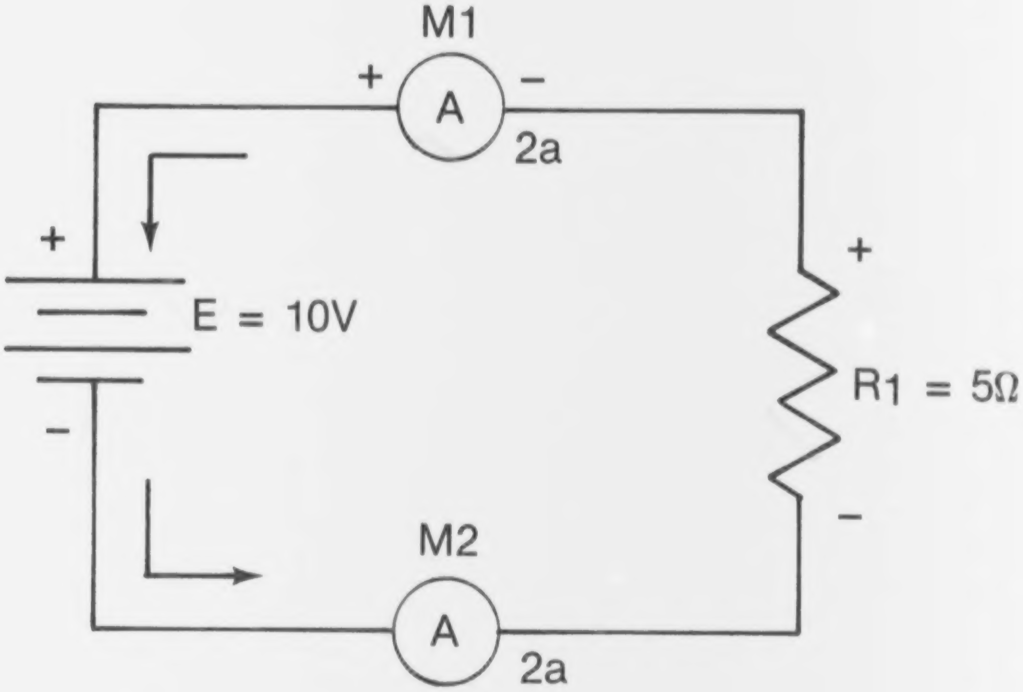
D. A load is connected in parallel with the resistor from which the voltage is tapped.

E. If the load draws appreciable current, the voltage division differs from the no-load condition.

Example: In the circuit below, the chassis is grounded at the point between R_2 and R_3. The equivalent resistance (R_{eq}) of R_3 and R_L is 5 ohms. The total resistance across the applied voltage is 25 ohms. The open load voltage across R_3 is 10 volts but the load voltage (with R_L connected) is 6 volts.

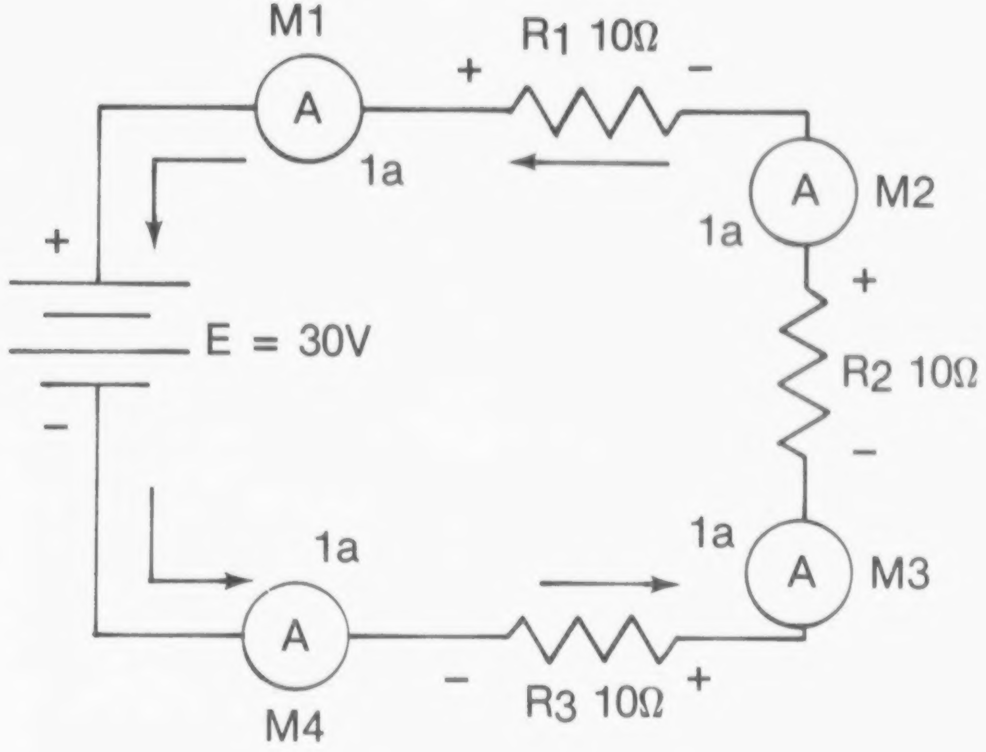


Simple Series Circuit


M1
+
−
A
2a
+
E = 10V
−
+
R1 = 5Ω
−
M2
A
2a

Current measured by M1 will equal that of M2.

Combined Series Circuit


M1
A
1a
R1 10Ω
+
–
A
M2
1a
+
R2 10Ω
–
+
–
E = 30V
1a
A
M3
1a
A
M4
–
R3 10Ω
+

Current measured by M1 will equal that of M2, M3, or M4.

Resistance in Parallel Circuits

The reciprocal of the total resistance of a parallel circuit is equal to the sum of the reciprocals of the individual resistances

or

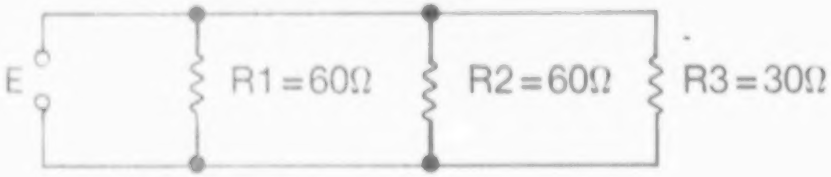
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \cdots$$

or

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \ldots}$$

The Reciprocal Resistance Method

For Calculating Total Resistance
in a Parallel Circuit: $1/R_T = 1/R1 + 1/R2 + 1/R3$



Step 1: Find Least Common Denominator and Add the Reciprocals:

Common Denominator = 60

Reciprocal of $R_1 = \frac{1}{60}$

Reciprocal of $R_2 = \frac{1}{60}$

Reciprocal of $R_3 = \frac{2}{60}$

$\frac{1}{60} + \frac{1}{60} + \frac{2}{60} = \frac{4}{60}$ = Total of Reciprocals

Step 2: Invert the Reciprocals:

$$\frac{1}{R_T} = \frac{4}{60}$$

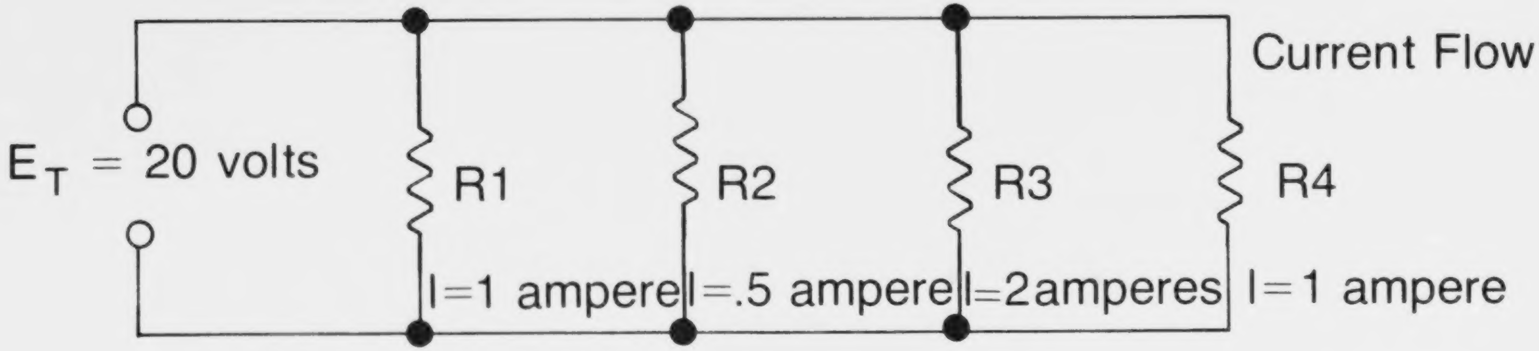
$$R_T = \frac{60}{4}$$

Step 3: Solve For R_T:

$$R_T = 15\Omega$$

(Less Than Any of the Individual Resistors)

Finding the Total Resistance in Parallel Circuits


Current Flow
E_T = 20 volts
R1
R2
R3
R4
I=1 ampere
I=.5 ampere
I=2amperes
I=1 ampere

$$R_T = \frac{E_T}{I_T} = \frac{20}{4.5} = 4.4 \text{ ohms}$$

$$R1 = \frac{20 \text{ volts}}{1 \text{ ampere}} = 20 \text{ ohms}$$

$$R2 = \frac{20 \text{ volts}}{.5 \text{ ampere}} = 40 \text{ ohms}$$

$$R3 = \frac{20 \text{ volts}}{2 \text{ amperes}} = 10 \text{ ohms}$$

$$R4 = \frac{20 \text{ volts}}{1 \text{ ampere}} = 20 \text{ ohms}$$

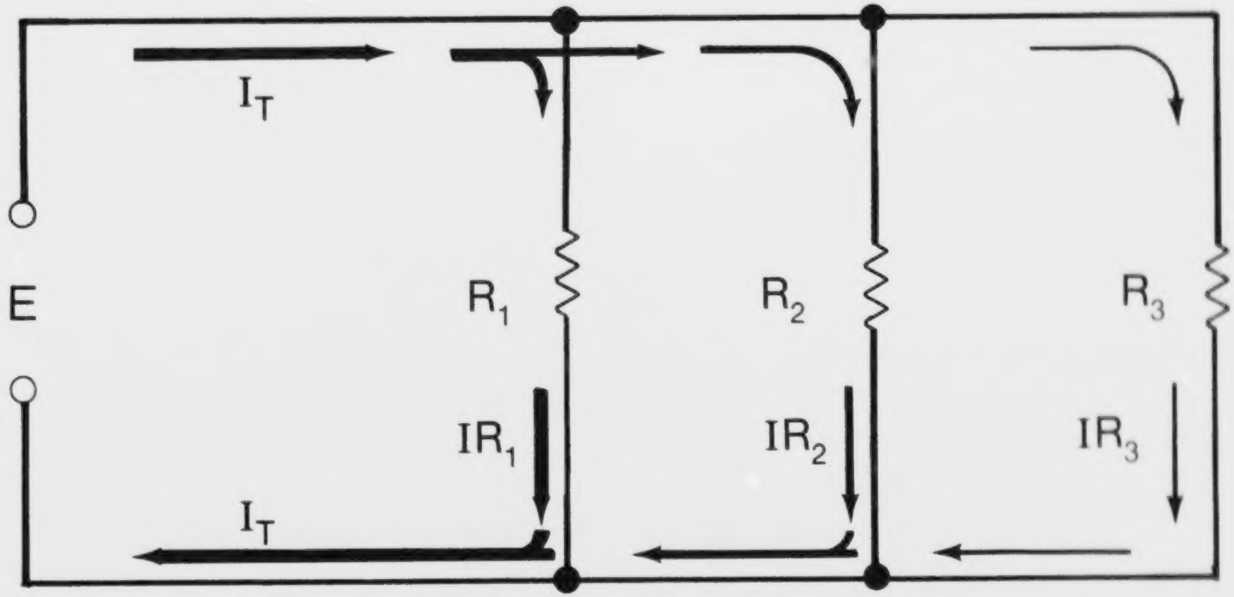
$$\frac{1}{R_T} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R4}$$

$$\frac{1}{R_T} = \frac{1}{20} + \frac{1}{40} + \frac{1}{10} + \frac{1}{20}$$

$$\frac{1}{R_T} = \frac{2 + 1 + 4 + 2}{40} = \frac{9}{40}$$

$$R_T = \frac{40}{9} = 4.4 \text{ ohms}$$

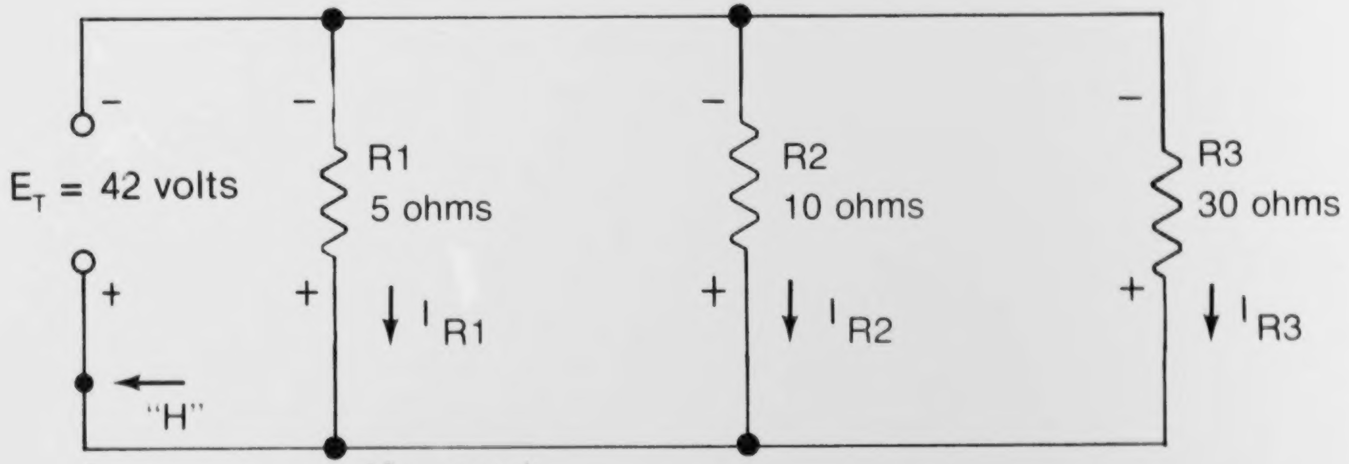
Current Flow in a Parallel Circuit


I_T
E
R_1
R_2
R_3
IR_1
IR_2
IR_3
I_T

The total current flowing through a parallel circuit is the sum of the currents flowing through each branch.

In the above circuit: $I_T = I_{R1} + I_{R2} + I_{R3}$

Finding Current in a Parallel Circuit



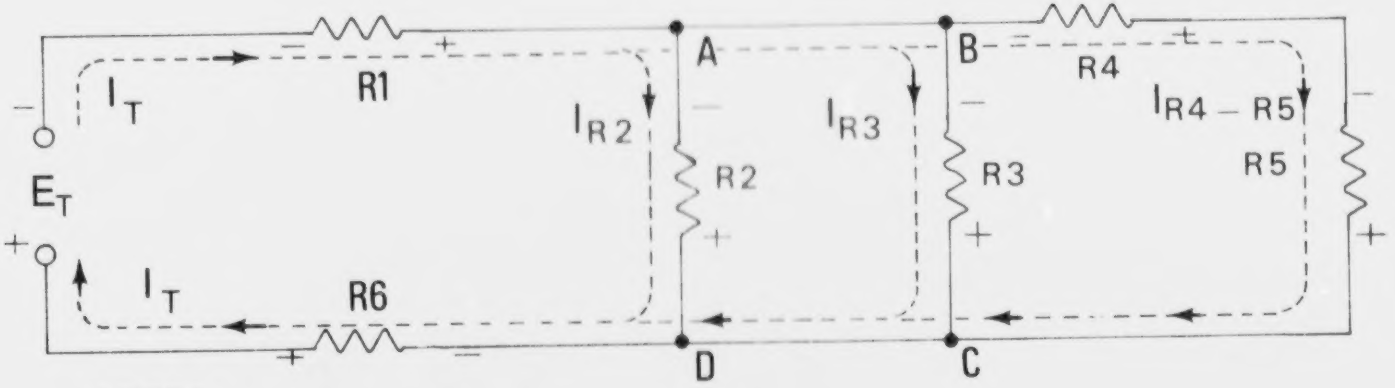
E_T = 42 volts
R1
5 ohms
R2
10 ohms
R3
30 ohms
I_{R1}
I_{R2}
I_{R3}
"H"
–
+

I_T = __________ (Amperes)

How much current is passing through point "H" in this circuit? There are two methods for determining total current in this circuit:

1. Find the current flowing through each branch (ex.: $I_{R1} = \frac{E}{R1}$), then add all 3 branch currents ($I_T = I_{R1} + I_{R2} + I_{R3}$).
2. Find the total resistance using the reciprocal resistance formula, then calculate total current ($I_T = \frac{E}{R_T}$).

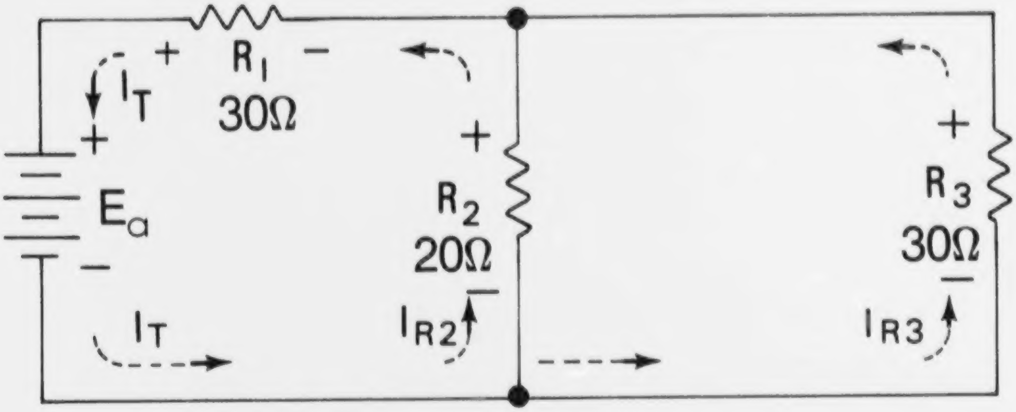
Steps to Simplify a Series-Parallel Circuit



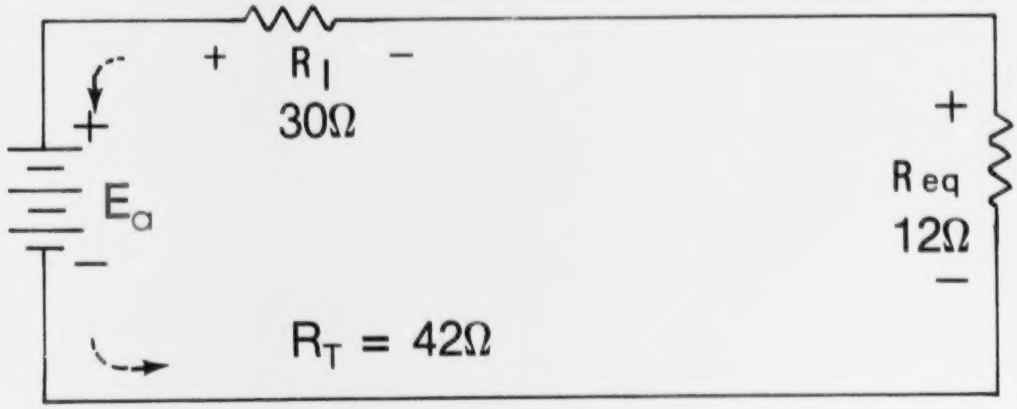
STEPS:

1. Trace Current Flow and Identify Voltage Drop Polarity (See Above)
2. Identify Nodes
   a. Current Division — A & B
   b. Current Return — C & D
3. Identify Resistors in Series With E_T: R1 & R6
4. Identify Resistors in Parallel: R2, R3, & (R4 + R5)
5. Identify Series-Parallel Resistors:
   a. R2, R3, & (R4 + R5) Become R_{eq} When the Reciprocal Resistance Formula is Applied
   b. R1 & R6 are in Series with R_{eq}
6. Determine Total Resistance: $RT = R1 + R_{eq} + R6$

Series-Parallel Circuit and Equivalent Circuit


+
R1
−
30Ω
IT
+
Ea
−
IT
+
R2
20Ω
−
IR2
+
R3
30Ω
−
IR3

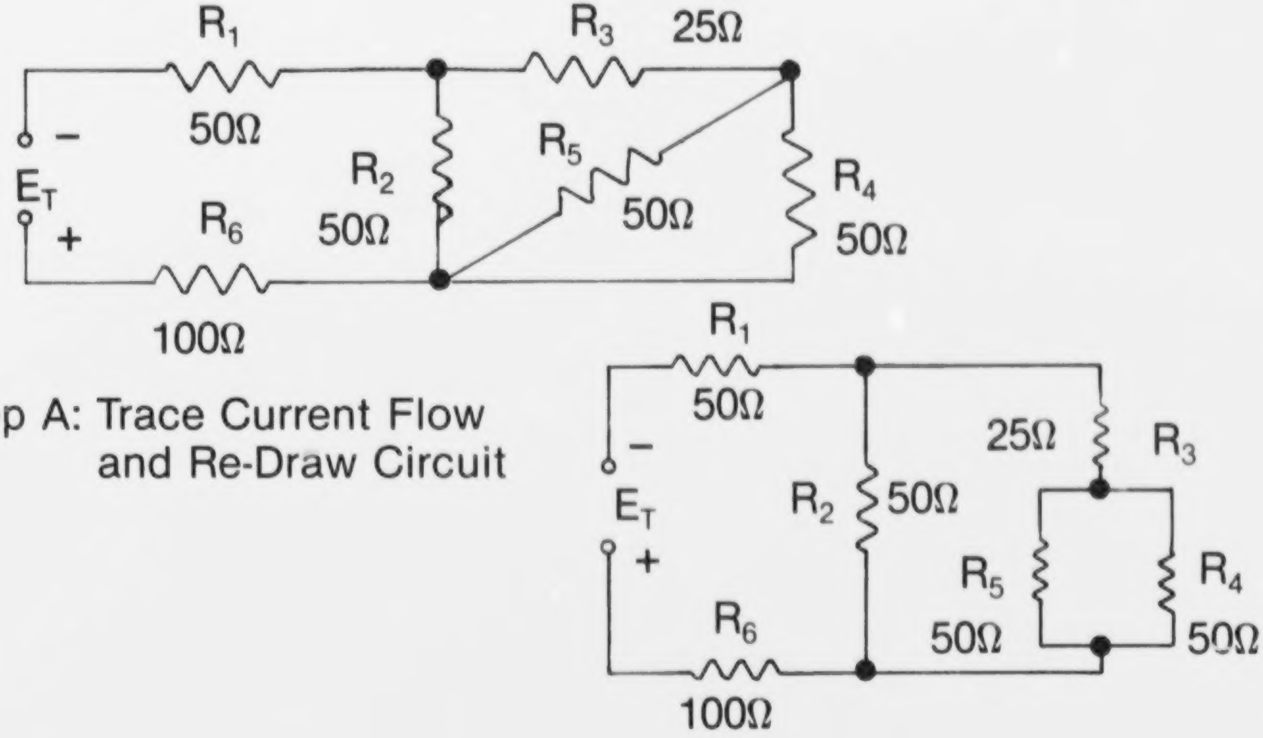
Circuit


+
R1
−
30Ω
+
Ea
−
RT = 42Ω
+
Req
12Ω
−

Equivalent Circuit

Circuit Reduction

(Step A)

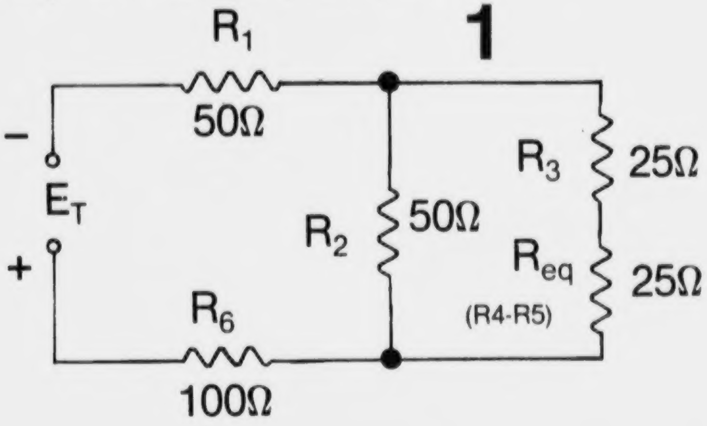

R$_1$
50Ω
R$_3$
25Ω
−
E$_T$
+
R$_2$
50Ω
R$_5$
50Ω
R$_4$
50Ω
R$_6$
100Ω
R$_1$
50Ω
−
E$_T$
+
25Ω
R$_3$
R$_2$
50Ω
R$_5$
50Ω
R$_4$
50Ω
R$_6$
100Ω

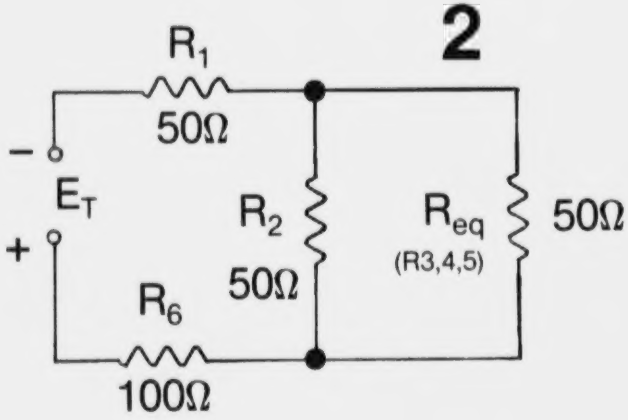
Step A: Trace Current Flow
and Re-Draw Circuit

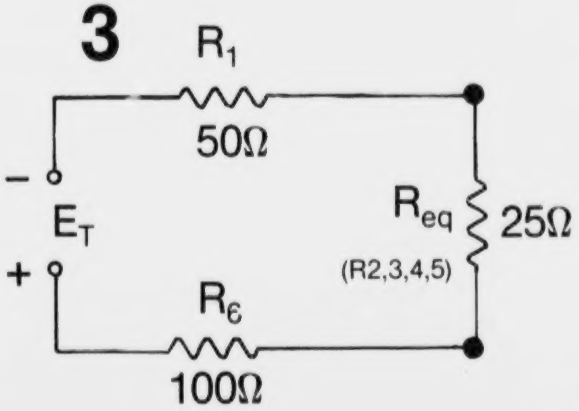
Circuit Reduction

(Step B)

Step B: Reduce Circuit


1
R1
50Ω
−
ET
+
R2
50Ω
R3
25Ω
Req
(R4-R5)
25Ω
R6
100Ω


2
R1
50Ω
−
ET
+
R2
50Ω
Req
(R3,4,5)
50Ω
R6
100Ω


3
R1
50Ω
−
ET
+
Req
(R2,3,4,5)
25Ω
R6
100Ω

$$R_T = R_1 + R_{eq} + R_6 = 175\Omega$$

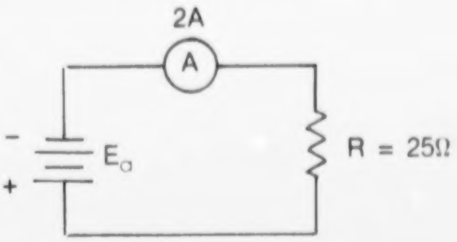
Power

- Is defined as the rate of doing work (w/t)
- Has the symbol "P"
- Can be calculated with formulas $P = IE$, $P = I^2 R$, $P = E^2/R$ Watt's Law
- Is measured in watts 1 watt = 1 ampere x 1 volt
- Is measured by a wattmeter

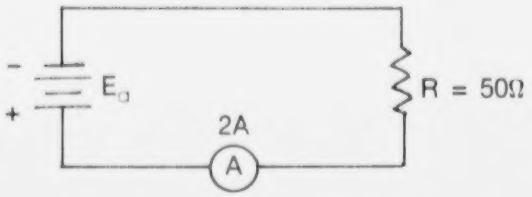
CIRCUITRY
UNIT III

ASSIGNMENT SHEET #1 — DETERMINE TOTAL VOLTAGE IN A SERIES CIRCUIT

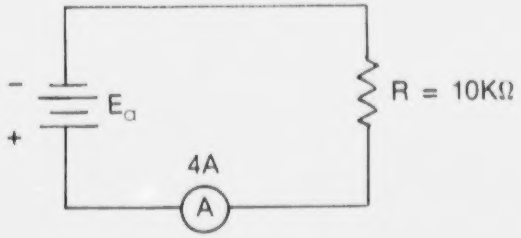
1. E_T = ____________



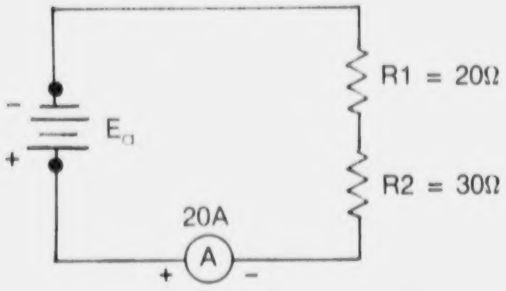
2. E_T = ____________



3. E_T = ____________

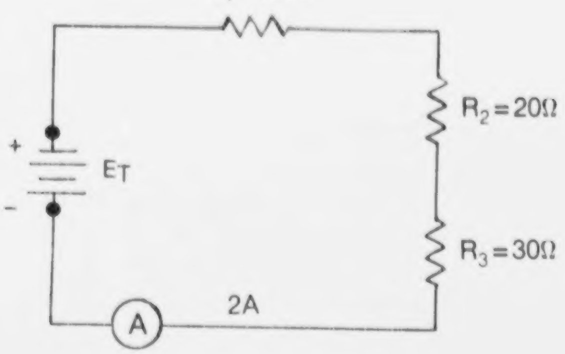

−
E_a
+
R = 10KΩ
4A
A

4. E_T = ____________

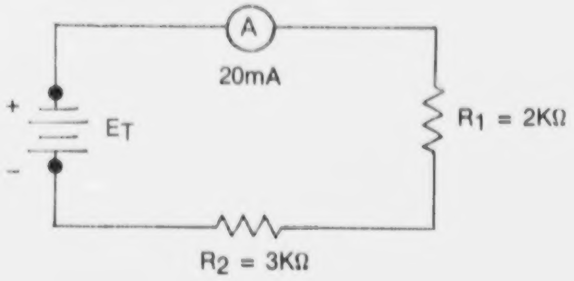

−
E_a
+
R1 = 20Ω
R2 = 30Ω
20A
A
+
−

ASSIGNMENT SHEET #1

5. E_T = ____________


$R_1 = 120\Omega$
$R_2 = 20\Omega$
$R_3 = 30\Omega$
+
−
E_T
A
2A

6. E_T = ____________

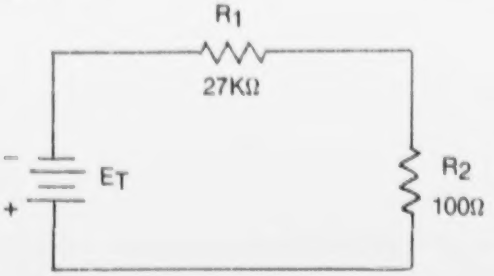

A
20mA
+
−
E_T
R_1 = 2KΩ
R_2 = 3KΩ

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #2 — DETERMINE VOLTAGE DROPS ACROSS RESISTANCES

1. True or false?

   _____ V_{R_1} is greater than V_{R_2}

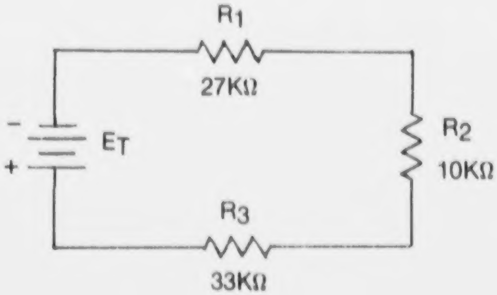

R1
27KΩ
−
+
ET
R2
100Ω

2. The largest voltage drop is

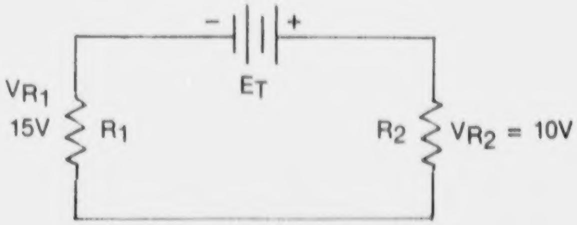
   _____a. V_{R_1}

   _____b. V_{R_2}

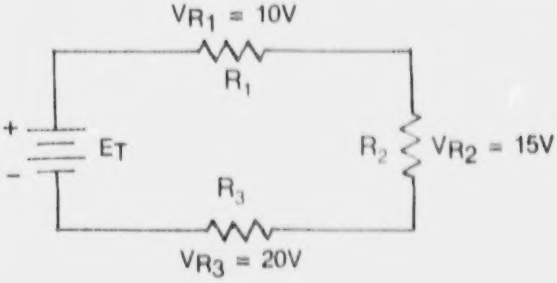
   _____c. V_{R_3}


R1
27KΩ
−
+
ET
R2
10KΩ
R3
33KΩ

3. E_T = ____________

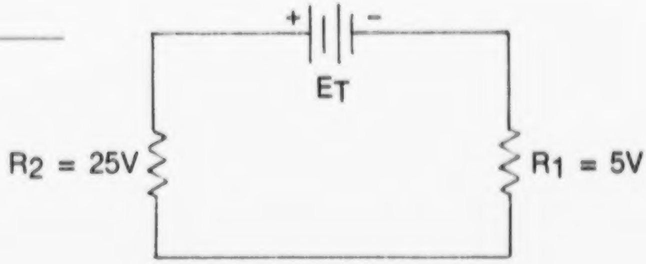

−
+
ET
VR1
15V
R1
R2
VR2 = 10V

4. E_T = ____________


VR1 = 10V
R1
+
−
ET
R2
VR2 = 15V
R3
VR3 = 20V

ASSIGNMENT SHEET #2

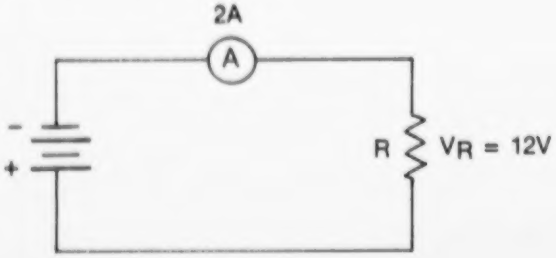
5. E_T = ______________


+
-
E_T
R_2 = 25V
R_1 = 5V

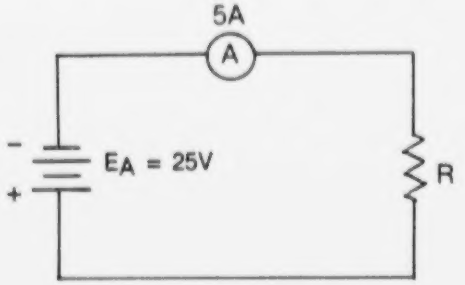
CIRCUITRY
UNIT III

ASSIGNMENT SHEET #3 — DETERMINE THE TOTAL RESISTANCE IN A SERIES CIRCUIT

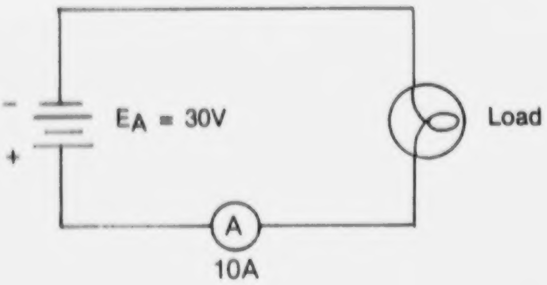
1. R_T = ______________



2. R_T = ______________



3. R_T = ______________

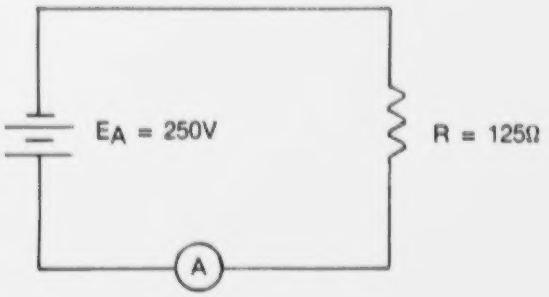

-
+
E_A = 30V
Load
A
10A

CIRCUITRY
UNIT III

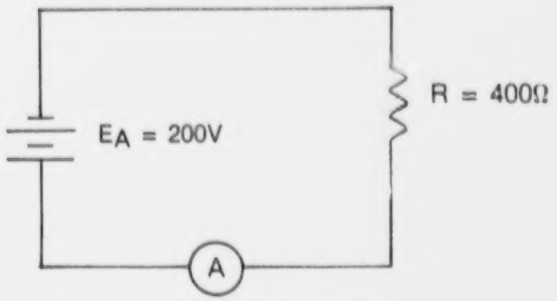
ASSIGNMENT SHEET #4 — DETERMINE CURRENT IN A SERIES CIRCUIT

Directions: Determine the current in the following series circuits. Be sure to indicate units.

1. I = ____________

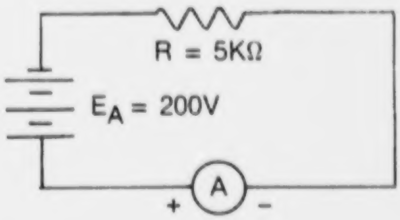

E_A = 250V
R = 125Ω
A

2. I = ____________


R = 400Ω
E_A = 200V
A

3. I = ____________

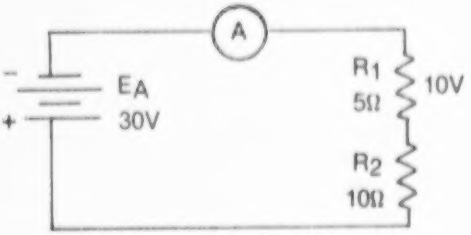
(NOTE: Give answer in milliamperes.)


R = 5KΩ
E_A = 200V
A
+
–

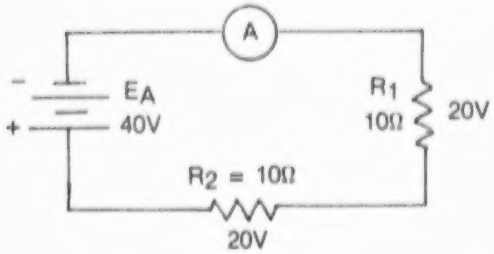
CIRCUITRY
UNIT III

ASSIGNMENT SHEET #5 — DETERMINE UNKNOWN CIRCUIT VALUES

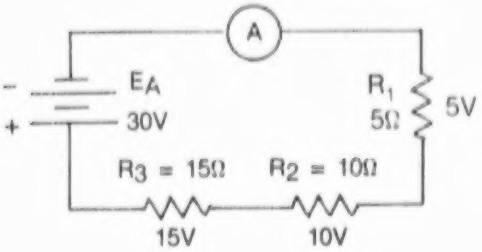
1. I_{R_1} = ____________


A
−
+
E_A
30V
R_1
5Ω
10V
R_2
10Ω

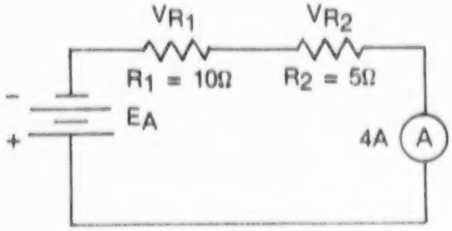
2. I_{R_2} = ____________


A
−
+
E_A
40V
R_1
10Ω
20V
R_2 = 10Ω
20V

3. I_{R_3} = ____________


A
−
+
E_A
30V
R_1
5Ω
5V
R_3 = 15Ω
R_2 = 10Ω
15V
10V

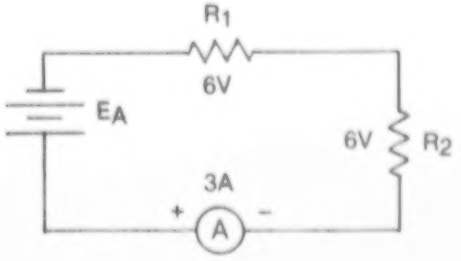
4. V_{R_2} = ____________


V_{R_1}
V_{R_2}
R_1 = 10Ω
R_2 = 5Ω
−
+
E_A
4A
A

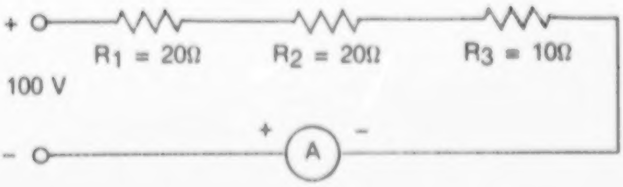
(NOTE: The Ohm's law formula applies to all parts of a circuit.)

ASSIGNMENT SHEET #5

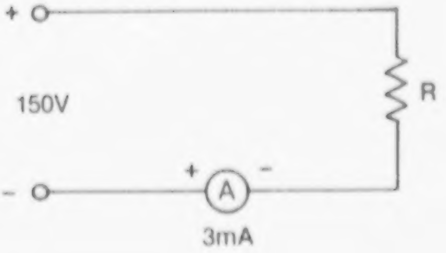
5. R_2 = __________


R_1
6V
E_A
6V
R_2
3A
+
A
−

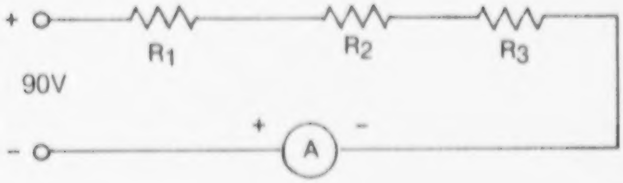
6. V_3 = __________


+
R_1 = 20Ω
R_2 = 20Ω
R_3 = 10Ω
100 V
+
A
−
−

7. R = __________



8. V_{R_1} = __________

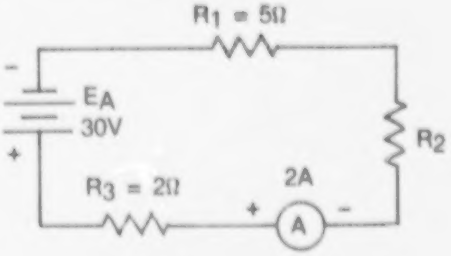

+
R_1
R_2
R_3
90V
+
A
−
−

(NOTE: All resistors are equal in value.)

CIRCUITRY
UNIT III

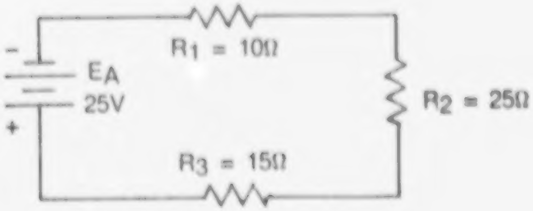
ASSIGNMENT SHEET #6 — DETERMINE UNKNOWN VALUES IN A RESISTIVE SERIES CIRCUIT

1. R_2 = ____________


$R_1 = 5\Omega$
-
E_A
30V
+
R_2
$R_3 = 2\Omega$
2A
+
A
-

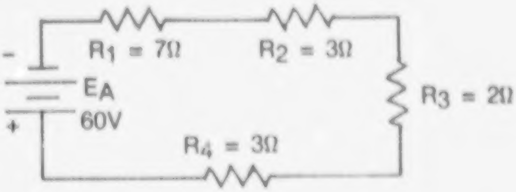
(NOTE: First solve for R_T.)

2. V_{R_1} = ____________


-
$R_1 = 10\Omega$
E_A
25V
+
$R_2 = 25\Omega$
$R_3 = 15\Omega$

(NOTE: To solve for any one part of a circuit, you must have two known values of that part. If solving for volts, you must find amps and ohms.)

3. Determine the quantities indicated.


-
$R_1 = 7\Omega$
$R_2 = 3\Omega$
E_A
60V
+
$R_3 = 2\Omega$
$R_4 = 3\Omega$

a. R_T = ______

b. I_T = ______

c. V_{R_1} = ______

d. I_{R_3} = ______

e. V_{R_2} = ______

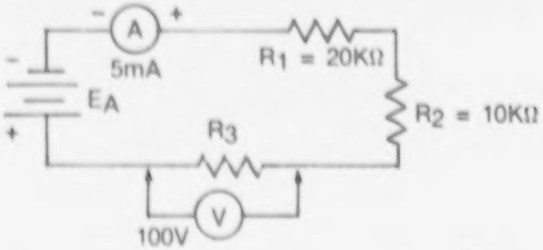
f. V_{R_3} = ______

g. V_{R_4} = ______

h. I_{R_4} = ______

ASSIGNMENT SHEET #6

4. Determine the quantities indicated.



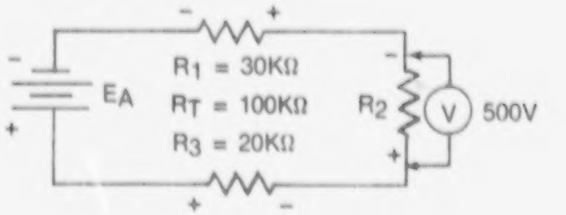
-
A
+
5mA
R_1 = 20KΩ
-
E_A
+
R_2 = 10KΩ
R_3
V
100V

a. I_T = ______ c. R_3 = ______ e. I_{R_1} = ______

b. V_{R_2} = ______ d. V_{R_1} = ______ f. E_A = ______

(NOTE: 5 mA = .005A.)

5. Determine the quantities indicated.

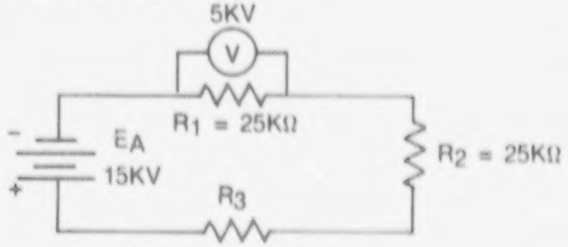


-
+
R_1 = 30KΩ
R_T = 100KΩ
R_3 = 20KΩ
-
E_A
+
R_2
-
+
V
500V
+
-

a. R_2 = ______ c. I_T = ______ e. V_{R_3} = ______

b. I_{R_3} = ______ d. V_{R_1} = ______ f. E_A = ______

6. Determine the quantities indicated.



5KV
V
R_1 = 25KΩ
-
E_A
15KV
+
R_2 = 25KΩ
R_3

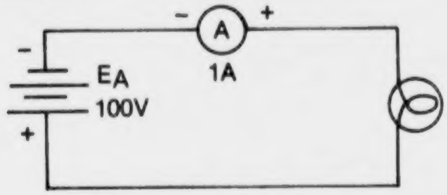
a. I_T = ______ c. R_3 = ______ e. R_T = ______

b. V_{R_2} = ______ d. V_{R_3} = ______ f. I_{R_3} = ______

ASSIGNMENT SHEET #6

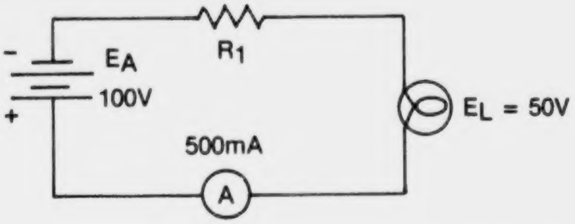
7. What resistance value will the lamp have?

R_L = ____________



8. In this circuit, if you wanted the lamp in problem 7 to operate at 50v, what would the value of R_1 have to be?

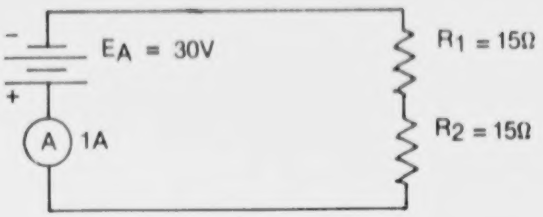
R_1 = ____________


–
E_A
100V
+
R_1
E_L = 50V
500mA
A

CIRCUITRY
UNIT III

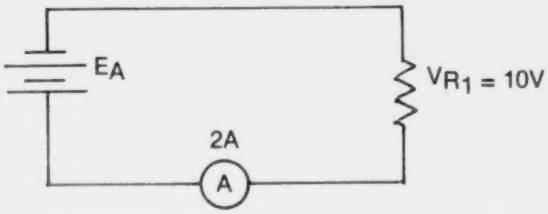
ASSIGNMENT SHEET #7 — COMPUTE THE POWER DISSIPATED IN A RESISTIVE SERIES CIRCUIT

1. P_T = ____________



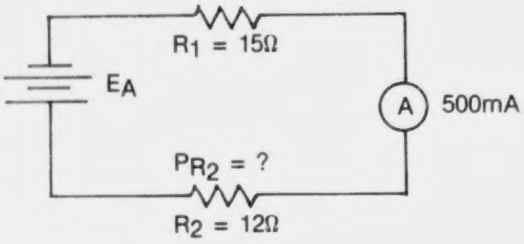
–
+
E_A = 30V
A
1A
R_1 = 15Ω
R_2 = 15Ω

2. P_{R_1} = ____________



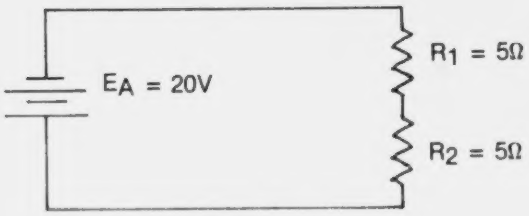
E_A
V_{R_1} = 10V
2A
A

3. P_{R_2} = ____________



R_1 = 15Ω
E_A
A
500mA
P_{R_2} = ?
R_2 = 12Ω

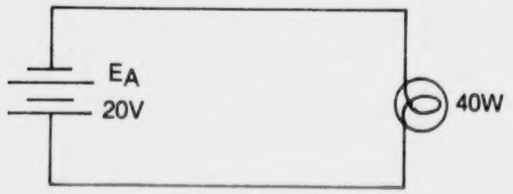
4. P_T = ____________



E_A = 20V
R_1 = 5Ω
R_2 = 5Ω

ASSIGNMENT SHEET #7

5. If the lamp is using 40 watts, the current equals ____________



CIRCUITRY
UNIT III

ASSIGNMENT SHEET #8 — CALCULATE CURRENT AND VOLTAGE IN PARALLEL CIRCUITS

1. Calculate quantities indicated.

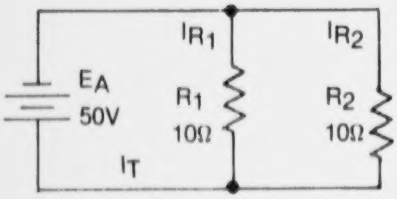
   a. E_{R_1}________

   b. I_{R_1}________

   c. E_{R_2}________

   d. I_{R_2}________

   e. I_T________


I_{R_1}
I_{R_2}
E_A
50V
R_1
10Ω
R_2
10Ω
I_T

2. Calculate quantities indicated.

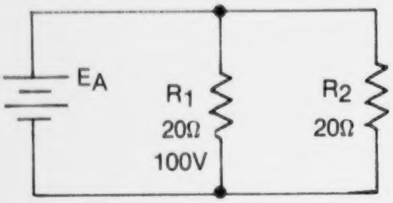
   a. I_{R_1}________

   b. E_{R_2}________

   c. I_{R_2}________

   d. I_T________

   e. E_A________


E_A
R_1
20Ω
100V
R_2
20Ω

3. Calculate quantities indicated.

   a. I_{R_1}________

   b. I_{R_2}________

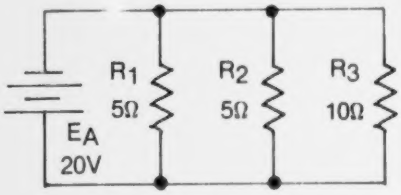
   c. I_{R_3}________

   d. I_T________

   e. E_{R_1}________

   f. E_{R_2}________

   g. E_{R_3}________


R_1
5Ω
R_2
5Ω
R_3
10Ω
E_A
20V

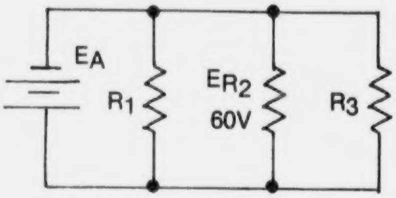
ASSIGNMENT SHEET #8

4. Calculate quantities indicated.

   a. E_{R_1} ________

   b. E_{R_3} ________

   c. E_A ________


E_A
R_1
E_{R2}
60V
R_3

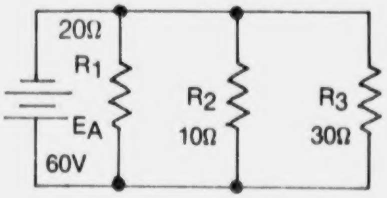
5. Calculate quantities indicated.

   a. I_1 ________

   b. I_2 ________

   c. I_3 ________

   d. I_T ________


20Ω
R_1
E_A
60V
R_2
10Ω
R_3
30Ω

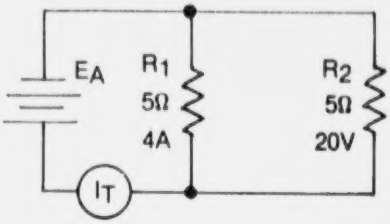
6. Calculate quantities indicated.

   a. I_2 ________

   b. I_T ________

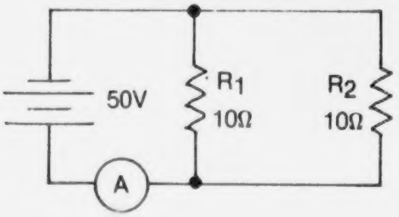
   c. E_{R_1} ________

   d. E_A ________


E_A
R_1
5Ω
4A
R_2
5Ω
20V
I_T

7. If you measured current where ammeter is located, what should it indicate?

____


50V
R_1
10Ω
R_2
10Ω
A

ASSIGNMENT SHEET #8

8. Calculate quantities indicated.

a. I_1________

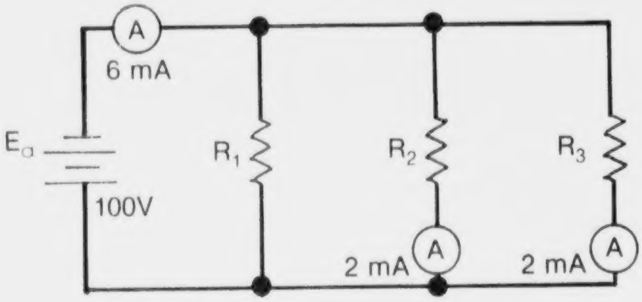
b. E_{R_1}________

c. E_A________

d. I_T________

e. E_{R_2}________

f. E_{R_3}________


A
6 mA
Ea
100V
R1
R2
R3
2 mA
A
2 mA
A

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #9 — CALCULATE RESISTANCE IN PARALLEL CIRCUITS

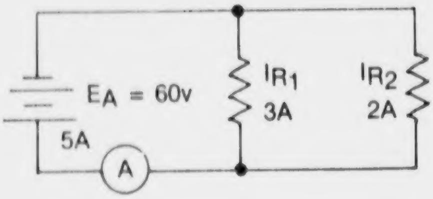
1. Calculate quantities indicated.

   a. R_1______

   b. R_2______

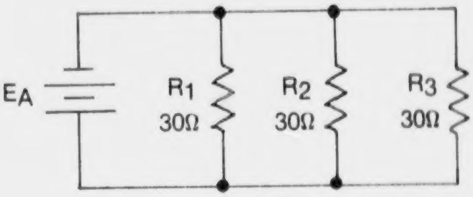
   c. R_T______

   d. $\frac{E_A}{I_T}$ = ______



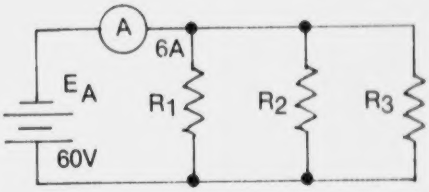
E_A = 60v
5A
A
I_{R1}
3A
I_{R2}
2A

2. Calculate R_T______



E_A
R_1
30Ω
R_2
30Ω
R_3
30Ω

3. a. Calculate R_T______

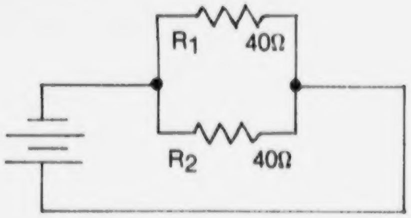


A
6A
E_A
60V
R_1
R_2
R_3

   b. If the three resistors are equal in value, R_1 = ______ ohms.

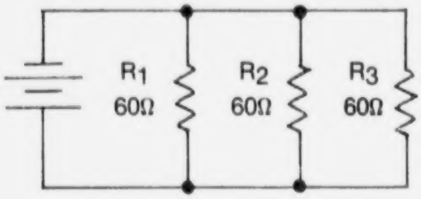
ASSIGNMENT SHEET #9

4. Calculate R_T_______



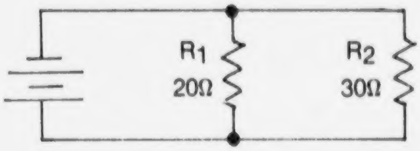
R_1
40Ω
R_2
40Ω

5. Calculate R_T_______



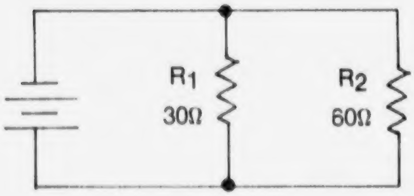
R_1
60Ω
R_2
60Ω
R_3
60Ω

6. Calculate R_T_______



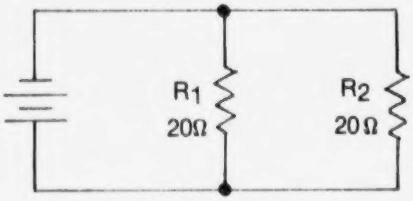
R_1
20Ω
R_2
30Ω

7. Calculate R_T_______



R_1
30Ω
R_2
60Ω

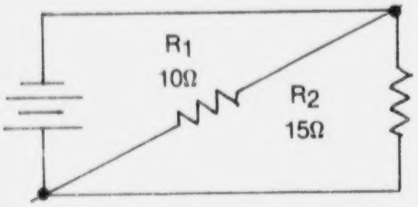
8. Calculate R_T_______



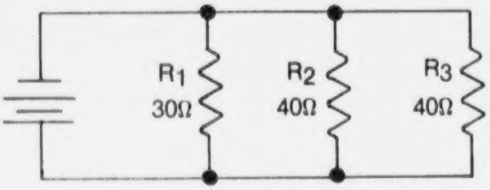
R_1
20Ω
R_2
20 Ω

ASSIGNMENT SHEET #9

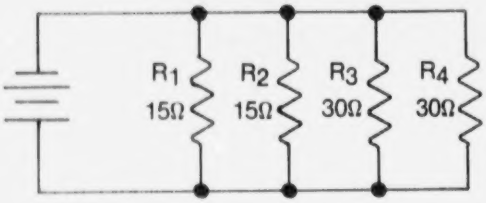
9. Calculate R_T______


R1
10Ω
R2
15Ω

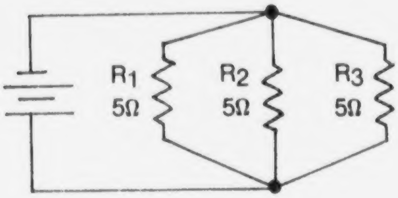
10. Calculate R_T______


R1
30Ω
R2
40Ω
R3
40Ω

11. Calculate R_T______


R1
15Ω
R2
15Ω
R3
30Ω
R4
30Ω

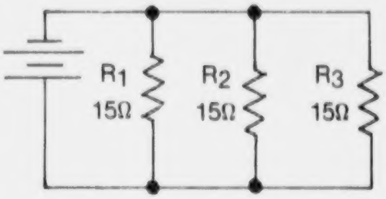
12. Calculate R_T______


R1
5Ω
R2
5Ω
R3
5Ω

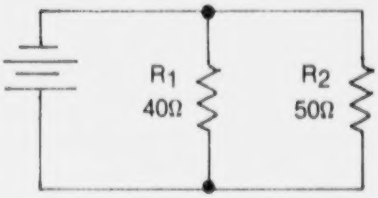
ASSIGNMENT SHEET #9

13. Match methods on the right with their circuit diagrams.

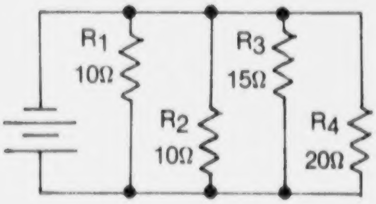
______a.


R1
15Ω
R2
15Ω
R3
15Ω

______b.


R1
40Ω
R2
50Ω

______c.


R1
10Ω
R2
10Ω
R3
15Ω
R4
20Ω

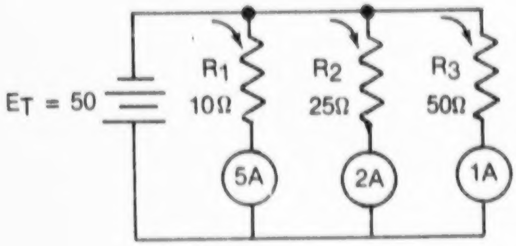
1. Unequal branch method (product over sum)
2. Reciprocal method
3. Equal branch method

(NOTE: Method 2 can, naturally, be used for all. Choose the fastest method.)

CIRCUITRY
UNIT III

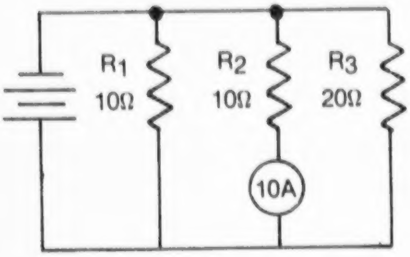
ASSIGNMENT SHEET #10 — CALCULATE POWER IN PARALLEL CIRCUITS

1. Calculate P_T


E_T = 50
R_1
10Ω
R_2
25Ω
R_3
50Ω
5A
2A
1A

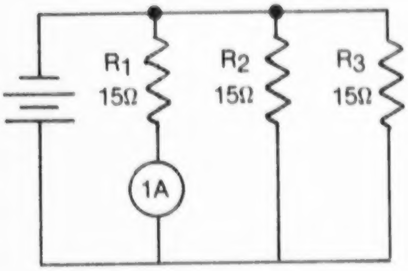
_______ Watts

2. Calculate P_T


R_1
10Ω
R_2
10Ω
R_3
20Ω
10A

_______ Watts

3. Calculate P_T

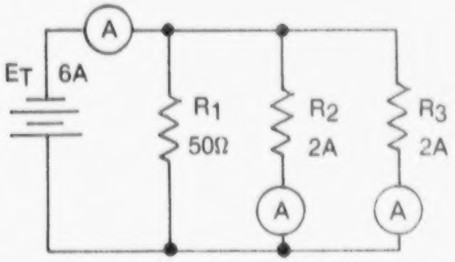

R_1
15Ω
R_2
15Ω
R_3
15Ω
1A

_______ Watts

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #11 — CALCULATE VARIOUS VALUES IN PARALLEL CIRCUITS

1. Calculate quantities indicated.


A
E_T
6A
R_1
50Ω
R_2
2A
R_3
2A
A
A

a. E_{R_1} ________

b. E_T ________

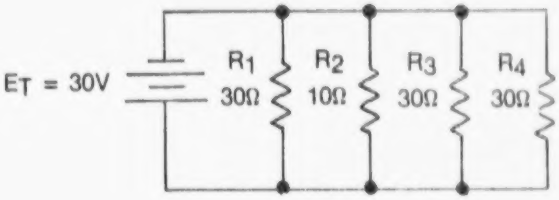
c. R_T ________

d. R_2 ________

e. R_3 ________

f. P_T ________

2. Calculate quantities indicated.


E_T = 30V
R_1
30Ω
R_2
10Ω
R_3
30Ω
R_4
30Ω

a. R_T ________

b. I_1 ________

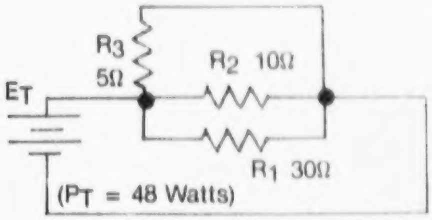
c. I_2 ________

d. I_3 ________

e. I_4 ________

f. I_T ________

3. Calculate quantities indicated.


R_3
5Ω
R_2 10Ω
E_T
R_1 30Ω
(P_T = 48 Watts)

a. R_T ________

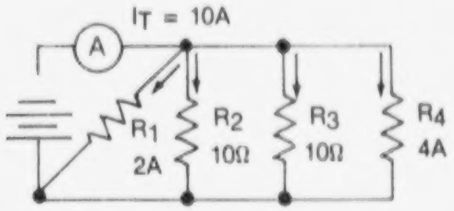
b. I_T ________

c. E_T ________

d. I_{R_1} ________

ASSIGNMENT SHEET #11

4. Calculate quantities indicated.


I_T = 10A
A
R_1
2A
R_2
10Ω
R_3
10Ω
R_4
4A

a. E_T__________

b. R_4__________

c. I_{R_2}__________

d. I_{R_3}__________

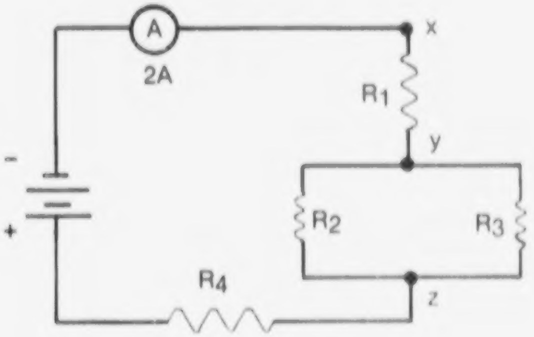
e. R_T__________

f. P_T__________

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #12 — TRACE CURRENT FLOW IN SERIES-PARALLEL CIRCUITS

1. Study the schematic and complete the statement below it.



Current will divide at Point ____________, and come back together at Point ____________.

2. From the circuit above, list the resistors:

in series ____________.

in parallel ____________.

3. In the circuit above (Resistors 2 and 3), which statements below are correct?

_____a. will carry a combined two amps of current

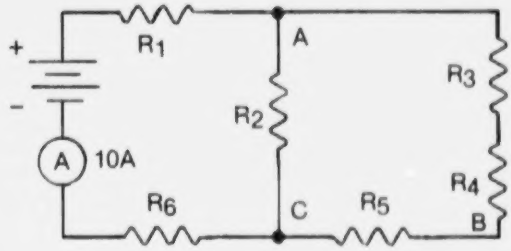
_____b. will each carry two amps of current

_____c. will carry a combined one amp of current

_____d. will **each** carry less than two amps of current

ASSIGNMENT SHEET #12

4. Study the schematic below and complete the questions below it.



a. At what point does current divide? ______________________

b. At what point does it come back together? ______________________

c. Does current divide more than once? ______________________

5. List the three resistors in the circuit above that form a series string.

a. ______________________

b. ______________________

c. ______________________

6. List the resistors in the circuit above in series with the source.

____

7. In the ciruit above, which statements below are correct?

_____a. R_2 is in parallel with R_3, R_4, and R_5

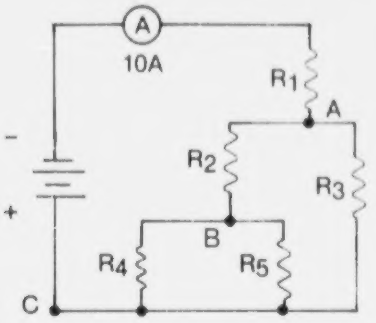
_____b. Less than 10 amps will flow through R_2

_____c. 10 amps will flow through R_6

_____d. Less than 10 amps will flow through R_3, R_4, R_5

ASSIGNMENT SHEET #12

8. Study the following schematic and answer the questions below it.



a. At what point does current first divide?______________________________

b. At what point does current next divide?______________________________

c. At what point does current all come back together?__________________

9. In the circuit, check the pairs of resistors that are in parallel with each other.

______a. R_1 and R_3

______b. R_2 and R_4

______c. R_2 and R_5

______d. R_4 and R_5

10. Answer these questions.

a. How many resistors are directly in series with the rest of the circuit?

b. Is the R_{eq} of R_4 and R_5 in series with R_2?

11. Check the statements that are correct.

______a. $I_{R_2} + I_{R_3} = 10$ amps

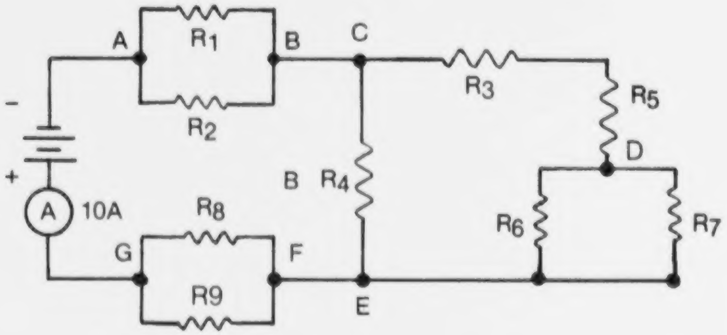
______b. An ammeter at Point C will measure 10 amps

______c. Current through R_5 will be more than through R_1

______d. $I_{R_4} + I_{R_5} = I_{R_2}$

ASSIGNMENT SHEET #12

12. Study the following schematic and answer the questions below it.



a. Current first divides at which point?____________________

b. Current next divides at which point?____________________

c. Does current also divide at Point D? Point F?____________________

d. How many resistors are in series with the source?____________________

e. Will there be a full 10 amps of current through R_7?____________________

f. Will there be a full 10 amps of current through R_4?____________________

g. Will there be a full 10 amps of current at Point G?____________________

h. Does total current go through R_2?____________________

i. Does a full 10 amps enter R_9?____________________

j. Will current be common through R_3 and R_5?____________________

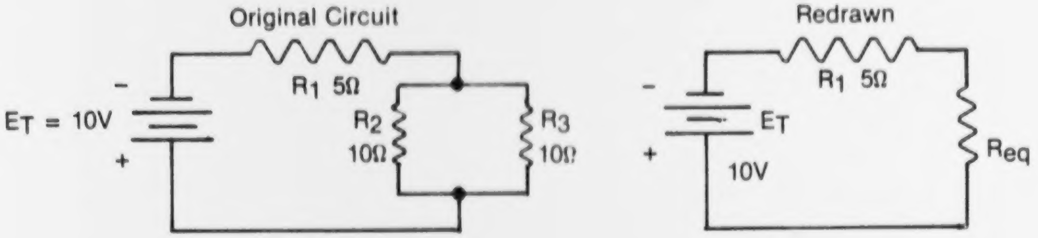
k. Does the full 10 amps of current enter Point D?____________________

l. Name the two resistors in string.____________________

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #13 — PERFORM EXERCISES IN CIRCUIT REDUCTION

1. This assignment is to reduce series-parallel circuits by redrawing them as series circuits, in this manner:



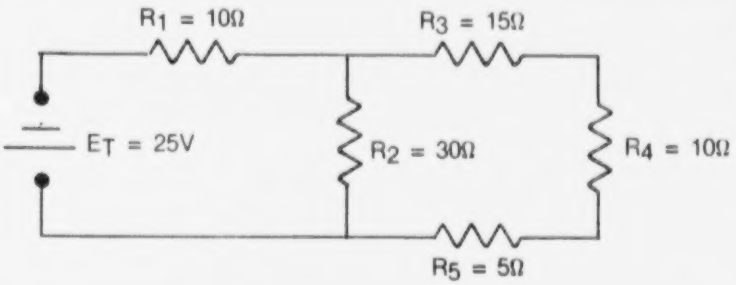
R_2 and R_3 in the original circuit have been combined into one resistor, which has become R_{eq} in the redrawn circuit. R_{eq} in the redrawn circuit will have the same resistance as R_2 and R_3 combined in the original circuit. In other words, R_{eq} in the redrawn circuit will be equal to R_{eq} of the original circuit.

a. What is the resistance value of R_{eq} in the redrawn circuit above?______

b. Redraw the series-parallel circuit with just one resistor and show its value.

ASSIGNMENT SHEET #13

2. Redraw the circuit below by combining R_3, R_4, and R_5. Show the new value.


$R_1 = 10\Omega$
$R_3 = 15\Omega$
$E_T = 25V$
$R_2 = 30\Omega$
$R_4 = 10\Omega$
$R_5 = 5\Omega$

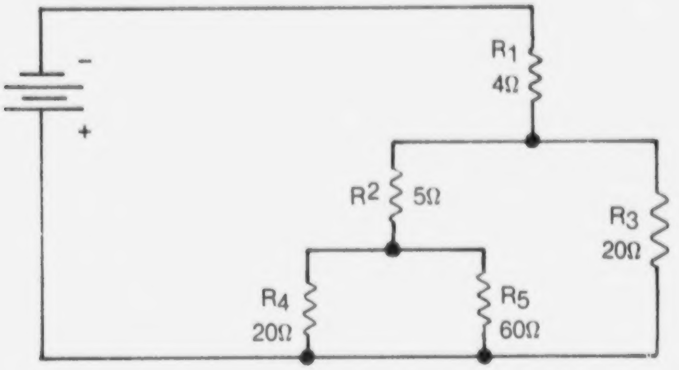
3. You should now have two resistors in parallel. Redraw the circuit again, combining the parallel branches. Show the equivalent value of the parallel branch.

4. Your circuit should now be a series circuit with two resistors. Redraw the circuit once more, showing one equivalent resistor. Show values, including I_T, on the schematic.

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #14 — SOLVE FOR TOTAL RESISTANCE

1. This assignment will combine circuit reductions and solve for total circuit resistance in more complex circuits. Use the steps cited in the Information Sheet and refer to it if necessary. Study the circuit below. Trace current flow and determine which resistors are in parallel.



a. First, find R_{eq} for R_4 and R_5 = ______________

b. Redraw circuit, showing R_4 and R_5 combined into one equivalent resistor. Show values.

2. Note that R_2 and R_{eq} are in series and are additive. Combine R_2 and R_{eq} into one equivalent resistor, R_{eq}. Redraw the circuit and show values.

ASSIGNMENT SHEET #14

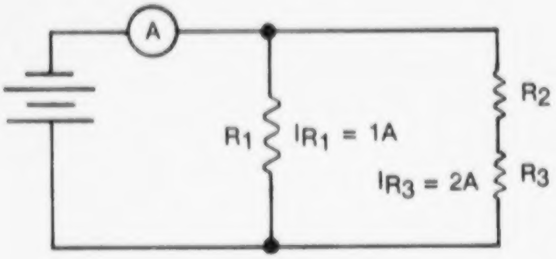
3. Notice now that the new R_{eq} is in parallel with R_3. Find the next R_{eq} and redraw the circuit with appropriate values shown.

4. Redraw the final circuit showing one equivalent resistor, R_T.

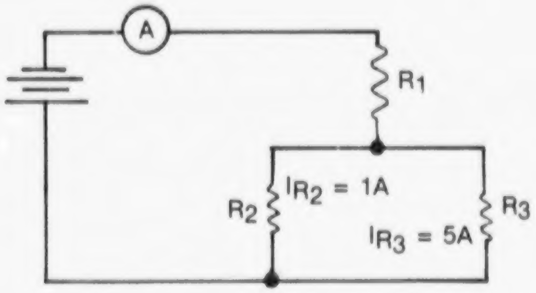
CIRCUITRY
UNIT III

ASSIGNMENT SHEET #15 — SOLVE FOR TOTAL CURRENT

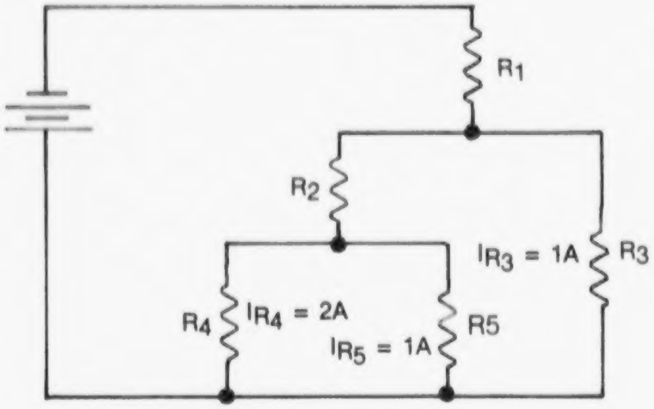
1. Study the circuit below. I_T = ____________.


A
R2
R1
I_{R_1} = 1A
I_{R_3} = 2A
R3

2. Find I_T = ____________.


A
R1
R2
I_{R_2} = 1A
I_{R_3} = 5A
R3

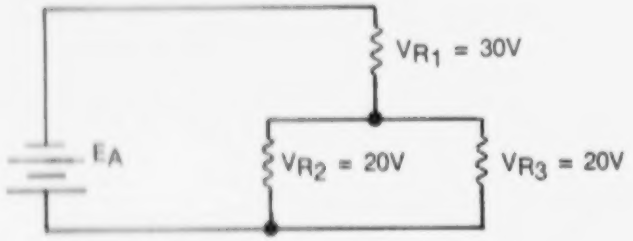
3. Find I_T = ____________.


R1
R2
I_{R_3} = 1A
R3
R4
I_{R_4} = 2A
I_{R_5} = 1A
R5

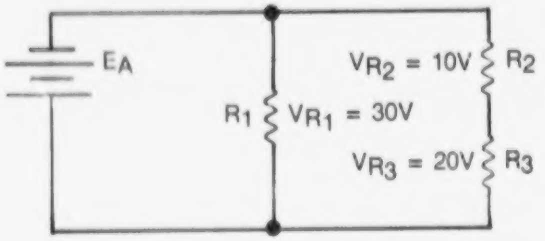
CIRCUITRY
UNIT III

ASSIGNMENT SHEET #16 — SOLVE FOR TOTAL VOLTAGE

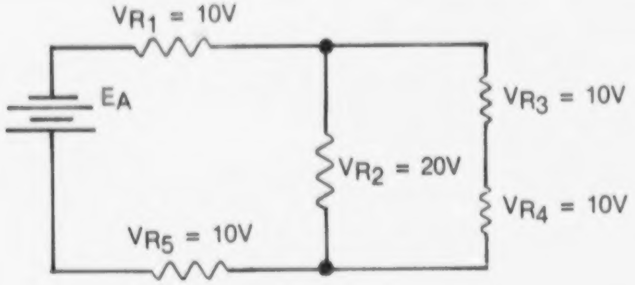
1. E_A = ______________________________


V_{R_1} = 30V
E_A
V_{R_2} = 20V
V_{R_3} = 20V

2. E_A = ______________________________


E_A
V_{R_2} = 10V
R_2
R_1
V_{R_1} = 30V
V_{R_3} = 20V
R_3

3. E_A = ______________________________

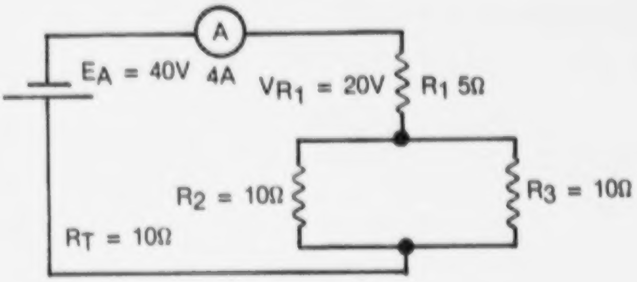

V_{R_1} = 10V
E_A
V_{R_3} = 10V
V_{R_2} = 20V
V_{R_4} = 10V
V_{R_5} = 10V

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #17 — SOLVE FOR BRANCH VOLTAGES AND CURRENTS IN SERIES-PARALLEL CIRCUITS

1. In this assignment, you will solve for branch voltage drop and current through branches.

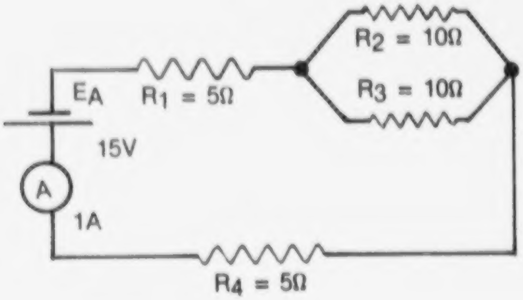
   a. In the schematic below, V_{R_3} = ______________________


A
E_A = 40V
4A
V_{R_1} = 20V
R_1 5Ω
R_2 = 10Ω
R_3 = 10Ω
R_T = 10Ω

   b. What is a V_{R_2}? ______________________

   c. Find I_{R_2} above. ______________________

2. In the circuit below, the voltage drop across R_4 is ______________________


R_2 = 10Ω
R_3 = 10Ω
E_A
R_1 = 5Ω
15V
A
1A
R_4 = 5Ω

3. In the circuit above, V_{R_2} = ______________________

4. In the circuit above, I_{R_3} = ______________________

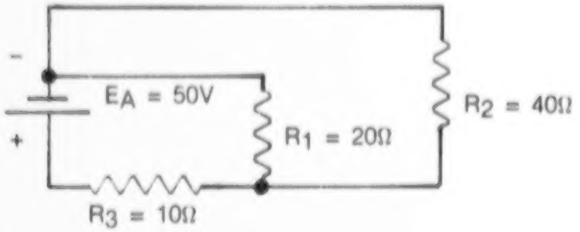
ASSIGNMENT SHEET #17

5. Study this circuit.

   a. Find V_{R_2} ____________________

   b. Find I_{R_1} ____________________

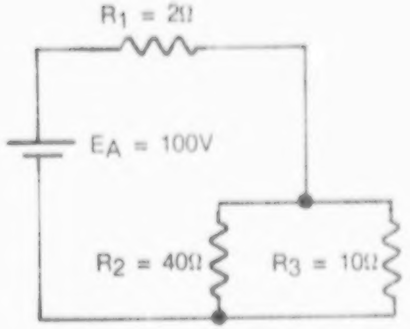
   c. Find I_{R_2} ____________________


–
+
$E_A = 50V$
$R_1 = 20\Omega$
$R_2 = 40\Omega$
$R_3 = 10\Omega$

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #18 — SOLVE FOR MULTIPLE VALUES OF VOLTAGES AND CURRENT

1. Solve for quantities indicated.


$R_1 = 2\Omega$
$E_A = 100V$
$R_2 = 40\Omega$
$R_3 = 10\Omega$

a. R_{eq} of R_2, R_3 = ____________

b. R_T = ____________

c. I_T = ____________

d. V_{R_1} = ____________

e. V_{R_2} = ____________

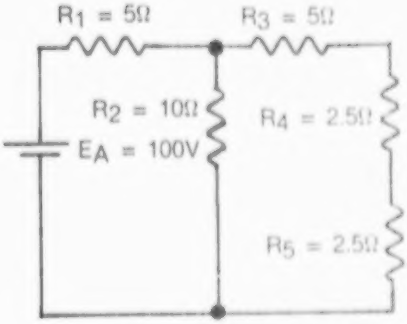
f. V_{R_3} = ____________

g. I_{R_1} = ____________

h. I_{R_2} = ____________

i. I_{R_3} = ____________

2. Solve for quantities indicated.


$R_1 = 5\Omega$
$R_3 = 5\Omega$
$R_2 = 10\Omega$
$E_A = 100V$
$R_4 = 2.5\Omega$
$R_5 = 2.5\Omega$

a. R_T = ____________

b. I_T = ____________

c. V_{R_1} = ____________

d. V_{R_2} = ____________

e. V_{R_3} = ____________

f. V_{R_4} = ____________

g. V_{R_5} = ____________

h. I_{R_2} = ____________

i. I_{R_3} = ____________

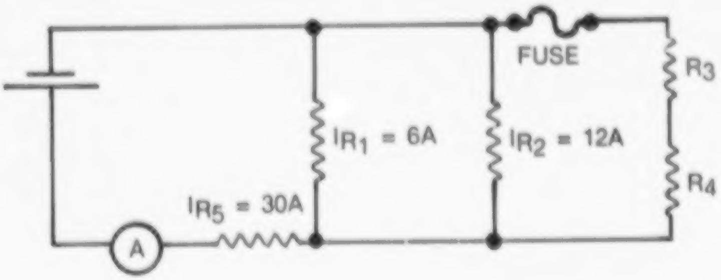
j. I_{R_4} = ____________

k. I_{R_5} = ____________

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #19 — ANSWER QUESTIONS REGARDING OPENS AND SHORTS IN SERIES-PARALLEL CIRCUITS

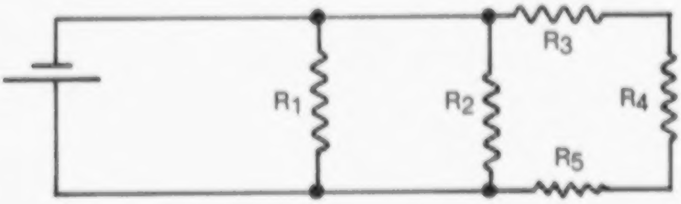
1. The fuse in the circuit below is rated at 10 amps. Analyze the circuit and answer the questions below it.


FUSE
R_3
I_{R_1} = 6A
I_{R_2} = 12A
R_4
I_{R_5} = 30A
A

a. How many amps will try to flow through the fuse? ________________

b. Will the fuse blow and create an open? ________________________

2. In the following circuit, an open suddenly occurs between R_3 and R_4. Answer the questions.


R_3
R_1
R_2
R_4
R_5

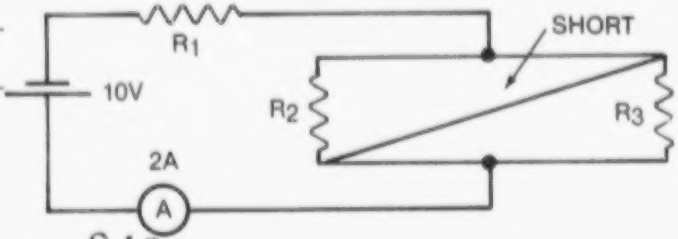
a. Total current will (increase, decrease, stay the same) ________________.

b. I_{R_3} will (increase, decrease, stay the same) ______________________.

3. In the shorted circuit below, the current flowing through

a. R_2 = ________

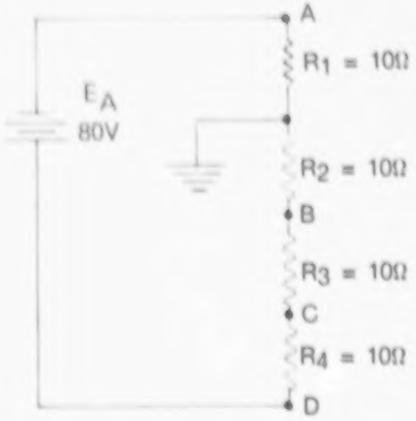
b. R_3 = ________


R_1
SHORT
10V
R_2
R_3
2A
A

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #20 — ANSWER QUESTIONS ABOUT GROUNDS AND VOLTAGE POLARITY

1. This assignment deals with voltage dividers and grounds, especially with grounds not located at the power source. Study the circuit and indicate the polarity and voltages requested.


A
$R_1 = 10\Omega$
E_A
80V
$R_2 = 10\Omega$
B
$R_3 = 10\Omega$
C
$R_4 = 10\Omega$
D

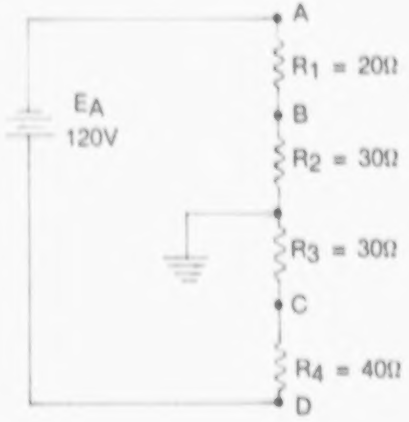
   a. The voltage between Point A and ground is ____________ (positive/negative)

   b. The voltage polarity between Point B and ground is ____________ (positive/negative)

   c. The voltage polarity between Point C and ground is ____________ (positive/negative)

   d. The voltage polarity between Point D and ground is ____________ (positive/negative)

2. Study the circuit and answer the questions.


A
$R_1 = 20\Omega$
E_A
120V
B
$R_2 = 30\Omega$
$R_3 = 30\Omega$
C
$R_4 = 40\Omega$
D

   a. The voltage and polarity from Point A to ground is ____________

   b. V_B (from Point B to ground) is ____________

   c. V_C (Point C to ground) is ____________

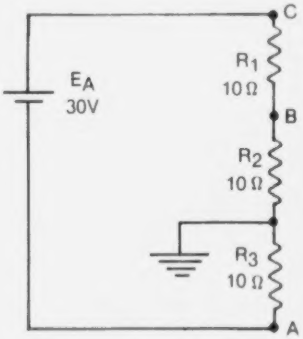
   d. V_D (Point D to ground) is ____________

   e. Voltage at Point D with respect to Point A is ____________

CIRCUITRY
UNIT III

ASSIGNMENT SHEET #21 — ANALYZE NO-LOAD AND LOAD CIRCUITS

1. In this assignment, you are going to perform a circuit analysis between a no-load circuit and a load circuit. Suppose we have a given circuit with no-load condition.


C
E_A
30V
R_1
10 Ω
B
R_2
10 Ω
R_3
10 Ω
A

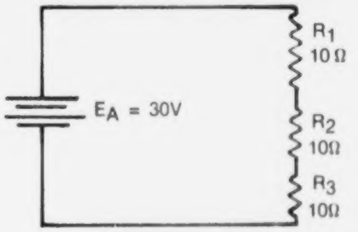
With respect to ground, what is the polarity and voltage at:

a. Point A ____________

b. Point B ____________

c. Point C ____________

2. First, let us record the quantities in the circuit with no-load or ground connected. Fill in the blanks with the proper values.


R_1
10 Ω
E_A = 30V
R_2
10Ω
R_3
10Ω

a. R_T ____________

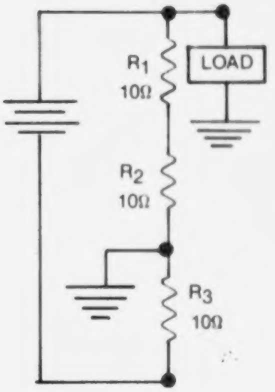
b. I_T ____________

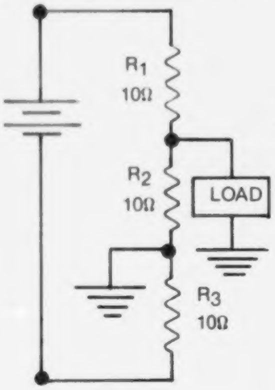
c. V_{R_1} ____________

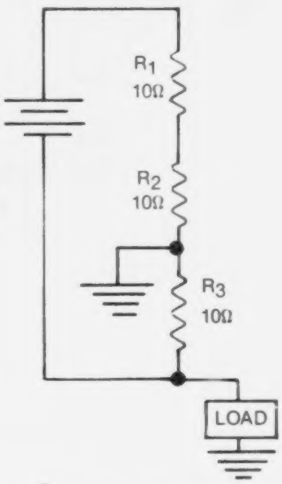
d. V_{R_2} ____________

e. V_{R_3} ____________

3. Suppose now that we want to connect a load that needs negative volts to operate. Which of the following circuits shows the proper load connection?


R_1
10Ω
LOAD
R_2
10Ω
R_3
10Ω

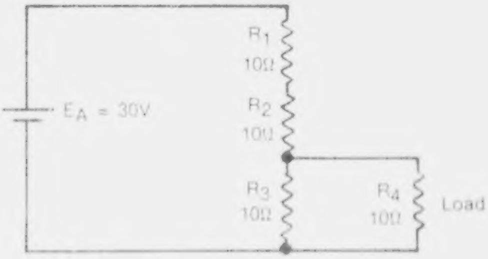

R_1
10Ω
R_2
10Ω
LOAD
R_3
10Ω


R_1
10Ω
R_2
10Ω
R_3
10Ω
LOAD

a. ____________ b. ____________ c. ____________

ASSIGNMENT SHEET #21

4. Connecting a load to the voltage divider gives a series-parallel circuit, like this:



The important thing to notice here is that R_3 now becomes a resistor in parallel instead of in series.

The load we want to operate needs 10 volts. (Do we still have the necessary 10 volts when we connect the load across R_3?) By adding the load, we know that many quantities are going to change. Solve for quantities indicated.

a. R_{eq} ______ (R_3 and R_4)

b. R_T ______

c. I_T ______

d. V_{R_1} ______

e. V_{R_2} ______

f. V_{R_3} ______

5. Compare the quantities in your no-load circuit with the quantities in your load circuit, and complete the boxes below, using arrows to show increases or decreases.

	R_T	I_T	E_{R_1}	E_{R_2}	E_{R_3}
Add R_4					

6. State the voltage drop across R_4. ______________________________

7. Will the load have 10 volts, connected as shown above? ______________

CIRCUITRY
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 50V
2. 100V
3. 40KV
4. 1000V or 1KV
5. 340V
6. 100V

Assignment Sheet #2

1. True
2. C
3. 25V
4. 45V
5. 30V

Assignment Sheet #3

1. 6
2. 5
3. 3

Assignment Sheet #4

1. 2A
2. 500 mA or 0.5 A
3. 40 mA

Assignment Sheet #5

1. 2A
2. 2A
3. 1A
4. 20V
5. 2
6. 20V
7. 50K Ω
8. 30V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #6

1. 8 Ω
2. 5V
3.
    - a. 15 Ω
    - b. 4A
    - c. 28V
    - d. 4A
    - e. 12V
    - f. 8V
    - g. 12V
    - h. 4A
4.
    - a. 5mA
    - b. 50V
    - c. 20K
    - d. 100V
    - e. 5mA
    - f. 250V
5.
    - a. 50K Ω
    - b. 10mA
    - c. 10mA
    - d. 300V
    - e. 200V
    - f. 1KV
6.
    - a. 200mA
    - b. 5KV
    - c. 25K Ω
    - d. 5KV
    - e. 75K Ω
    - f. 200mA
7. 100 Ω
8. 100 Ω

Assignment Sheet #7

1. 30W
2. 20W
3. 3W
4. 40W
5. 2A

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #8

1. a. 50v
   b. 5a
   c. 50v
   d. 5a
   e. 10a

2. a. 5a
   b. 100v
   c. 5a
   d. 10a
   e. 100v

3. a. 4a
   b. 4a
   c. 2a
   d. 10a
   e. 20v
   f. 20v
   g. 20v

4. a. 60v
   b. 60v
   c. 60v

5. a. 3a
   b. 6a
   c. 2a
   d. 11a

6. a. 4a
   b. 8a
   c. 20v
   d. 20v

7. 10a

8. a. 2ma
   b. 100v
   c. 100v
   d. 6ma
   e. 100v
   f. 100v

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #9

1. a. 20Ω
   b. 30Ω
   c. 12Ω
   d. 12Ω
2. 10Ω
3. a. 10Ω
   b. 30Ω
4. 20Ω
5. 20Ω
6. 12Ω
7. 20Ω
8. 10Ω
9. 6Ω
10. 12Ω
11. 5Ω
12. 2Ω
13. a. (3)
    b. (1)
    c. (2)

Assignment Sheet #10

1. 400
2. 2500 watts
3. 45 watts

Assignment Sheet #11

1. a. 100V
   b. 100V
   c. 16.7Ω
   d. 50Ω
   e. 50Ω
   f. 600W
2. a. 5Ω
   b. 1A
   c. 3A
   d. 1A
   e. 1A
   f. 6A

ANSWERS TO ASSIGNMENT SHEETS

3. a. 3Ω
   b. 4A
   c. 12V
   d. 0.4a or 400ma

4. a. 20v
   b. 5Ω
   c. 2a
   d. 2a
   e. 2Ω
   f. 200 watts

Assignment Sheet #12

1. Point Y, Point Z
2. In series — R_1 and R_4
   In parallel — R_2 and R_3
3. a and d
4. a. Point C
   b. Point A
   c. No
5. R_3, R_4, R_5
6. R_1, R_6
7. All are correct
8. a. Point A
   b. Point B
   c. Point C
9. d
10. a. One (R_1)
    b. Yes
11. a, b, d

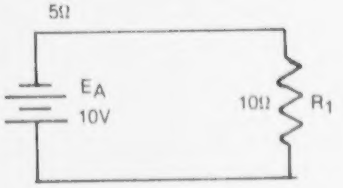
ANSWERS TO ASSIGNMENT SHEETS

12. a. Point A
    b. Point C
    c. Yes, Yes
    d. None
    e. No
    f. No
    g. Yes
    h. No
    i. No
    j. Yes
    k. No
    l. R_3 and R_5

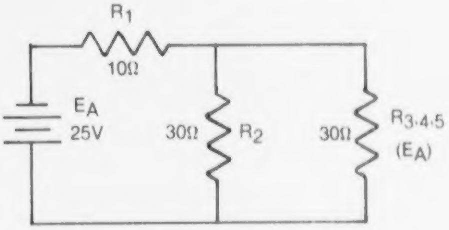
Assignment Sheet #13

1. a.

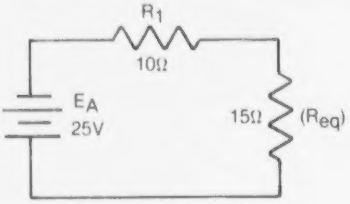
   b.


5Ω
E_A
10V
10Ω
R_1

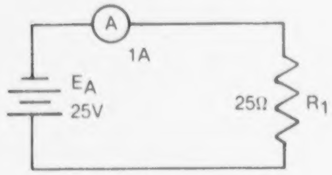
2.


R_1
10Ω
E_A
25V
30Ω
R_2
30Ω
R_3·4·5
(E_A)

3.


R_1
10Ω
E_A
25V
15Ω
(R_eq)

4.

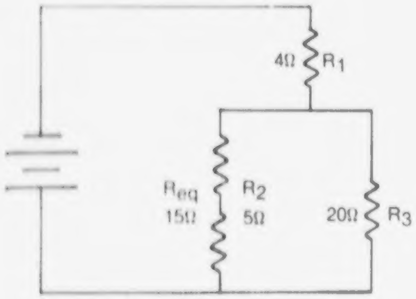

A
1A
E_A
25V
25Ω
R_1

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #14

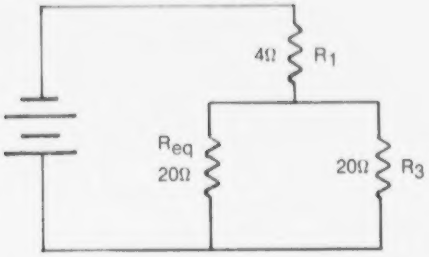
1. a. 15 ohms

   b.



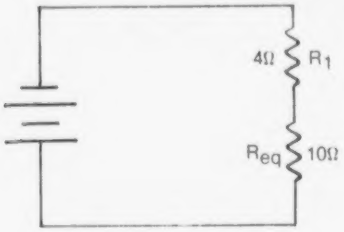
4Ω
R₁
Req
15Ω
R₂
5Ω
20Ω
R₃

2.



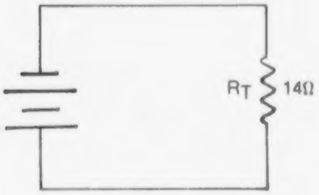
4Ω
R₁
Req
20Ω
20Ω
R₃

3.



4Ω
R₁
Req
10Ω

4.



Assignment Sheet #15

1. 3a
2. 6a
3. 4a

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #16

1. 50v
2. 30v
3. 40v

Assignment Sheet #17

1. a. 20v
   b. 20v
   c. 2a
2. 5v
3. 5v
4. 0.5 or 500ma
5. a. 21.4v
   b. 1.43A
   c. .715A

Assignment Sheet #18

1. a. 8
   b. 10
   c. 10a
   d. 20v
   e. 80v
   f. 80v
   g. 10a
   h. 2a
   i. 8a
2. a. 10
   b. 10a
   c. 50v
   d. 50v
   e. 25v
   f. 12.5v
   g. 12.5v
   h. 5a
   i. 5a
   j. 5a
   k. 5a

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #19

1. a. 12a
   b. Yes
2. a. Decrease
   b. Decrease
3. a. Zero
   b. Zero

Assignment Sheet #20

1. a. 20v negative
   b. 20v positive
   c. 40v positive
   d. 60v positive
2. a. Negative 50v
   b. Negative 30v
   c. Positive 30v
   d. Positive 70v
   e. Positive 120v

Assignment Sheet #21

1. a. Negative 10 volts
   b. Positive 10 volts
   c. Positive 20 volts
2. a. 30
   b. 1a
   c. 10v
   d. 10v
   e. 10v

ANSWERS TO ASSIGNMENT SHEETS

3. c
4. a. 5
   b. 25
   c. 1.2a
   d. 12v
   e. 12v
   f. 6v
5.

6. 6 volts
7. No

CIRCUITRY
UNIT III

JOB SHEET #1 — VERIFY OHM'S LAW

A. Equipment and materials needed

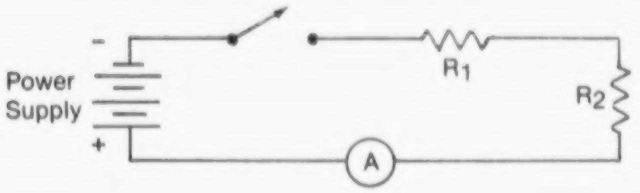
1. Regulated power supply
2. Switch (SPST)
3. Two resistors: R_1 = 4.7K, 1/2 watt minimum; R_2 = 1K, 1 watt.
4. Multimeter

B. Procedure

1. Measure and record the ohms value of the two resistors

   ____________________ ____________________

2. Connect a circuit as shown in the following schematic (Figure 1).



3. Close the switch and adjust the power supply output to 24 volts.
4. Use the voltmeter to measure the following voltages:

   V_{R_1} = ______ V_{R_2} = ______ E_A = ______

5. Read and record the ammeter indication I = ______.
6. Disconnect the circuit by opening the switch.
7. Use Ohm's law and compute:

   I_{R_1} = ______ I_{R_2} = ______ I_T = ______ ($I_T = \frac{E_A}{R_T}$)

8. Compare the values of the various current computations, and explain the differences, if any, in these values.

JOB SHEET #1

9. Return equipment and materials to their proper storage area.

   (NOTE: The following questions may be discussed in class:

   a. Is the current the same through all components in a series circuit? Why?

   b. Are the voltages the same across all components in a series circuit? Why?)

CIRCUITRY
UNIT III

JOB SHEET #2 — ANALYZE A SERIES CIRCUIT

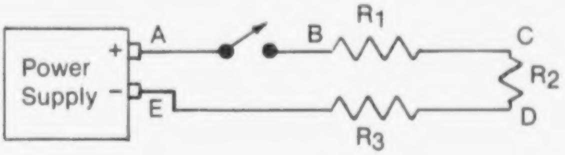
A. Equipment and materials needed

1. Regulated power supply
2. Switch (SPST)
3. Two resistors of the same value
4. One resistor of a different value
5. Multimeter

(NOTE: Your instructor will give you the value of voltage and the value of resistors to use.)

B. Procedure

1. Connect the circuit according to the following schematic.



2. Close the switch.
3. Use the voltmeter to read and record

E_A = ______________

V_{R_1} = ______________

V_{R_2} = ______________

V_{R_3} = ______________

4. Add the voltage drops across the three resistors and compare the sum with the amount of applied voltage.

JOB SHEET #2

5. Compare the voltage drops across R_1 and R_2 having the same value of ohms and with the voltage drop across the other resistor.

   (NOTE: Discuss how applied voltage distributes itself across resistances of unequal or of equal value.)

6. Identify the most negative point in the circuit.

7. Return equipment and materials to their proper storage area.

CIRCUITRY
UNIT III

JOB SHEET #3 — MEASURE VOLTAGE, CURRENT, AND RESISTANCE IN A PARALLEL CIRCUIT

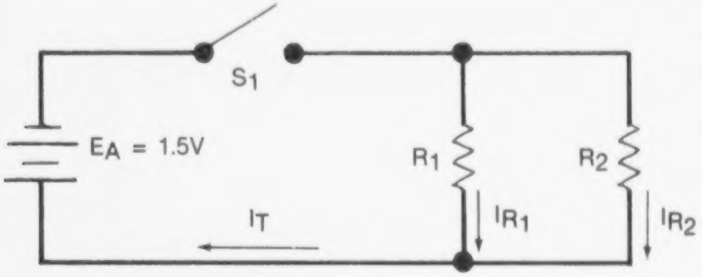
A. Equipment and materials needed

1. 1.5 battery or equivalent
2. Two small resistors of equal value or two small lamps

   (NOTE: Ask instructor to give values.)
3. Multimeter
4. Switch (SPST)
5. Wire to complete circuit

B. Procedure

1. Construct a parallel resistive circuit according to the schematic below.



2. Close switch S_1.
3. Measure and record applied voltage (E_A).______________
4. Measure and record voltage across R_1, and across R_2.______________
5. Compare recorded voltages.

   Are they all equal?______________

   Explain why.____

   ____
6. Open switch S_1.
7. Connect ammeter in series with R_1.

JOB SHEET #3

8. Close switch S_1 and read and record current (I_{R_1}).____________

9. Open switch S_1.

10. Disconnect ammeter from R_1 branch and connect it in series with R_2.

11. Close switch S_1 and read and record current (I_{R_2}).____________

12. Open switch S_1.

13. Disconnect ammeter from R_1 branch, and connect it in series with the voltage source (E_A) and switch S_1.

14. Close switch S_1 and read and record main current (I_T).____________

15. Open switch S_1.

16. Are recorded currents I_{R_1} and I_{R_2} equal? Explain why or why not.________
____

17. Add I_{R_1} and I_{R_2}. Does the sum equal I_T? Explain why or why not.________
____

18. Close switch; if lamps were used for R_1 and R_2, note that both lamps are glowing.

19. Disconnect R_2 from circuit.

20. Record ammeter indication, and, if R_1 and R_2 are lamps, note any changes in R_1 operation when R_2 (lamp) was removed.____________

21. Replace R_2, and remove R_1 from circuit.

22. Record ammeter indication, and note any changes in R_2 operation, if applicable.
____

23. Reconnect R_1.

24. Using voltmeter, read and record applied voltage (E_A), E_{R_1}, and E_{R_2}.____________

25. Using measured E_A and I_T, compute total resistance of the circuit (R_T).____________

26. Using measured voltage and current values, compute R_1 and R_2, and from these figures compute R_T.______________________________

27. If R_1 and R_2 are lamps, explain changes in lamp operation when one lamp was removed from the circuit.______________________________
____

28. Return equipment and materials to their proper storage area.

CIRCUITRY
UNIT III

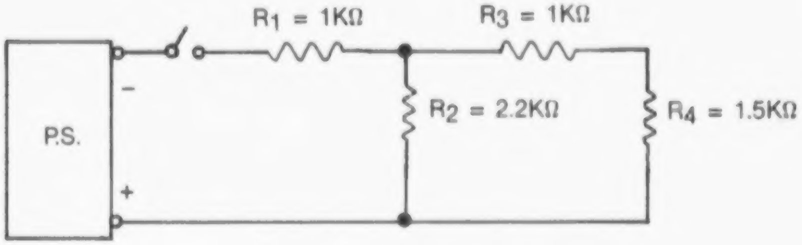
JOB SHEET #4 — ANALYZE A SERIES-PARALLEL CIRCUIT

A. Equipment and materials needed

1. DC power supply
2. Multimeter
3. Two 1000, one 1500, and one 2200 ohm resistors, ½W or more
4. Switch — SPST

B. Procedure

1. Connect the resistors as shown in the schematic.
2. Adjust the power supply to 20V and close the switch.



3. Measure and record the voltage drop across each resistor (V_1, V_2. . .). ______________
4. Measure and record the current through each resistor (I_1, I_2. . .). ______________
5. Compute the power used by each resistor using the values measured in Steps 3 and 4 ($P_1 = E_1I_1$, etc.). ______________
6. Measure and record E_A and I_T. ______________
7. Compute R_T using the measurements of Step 6. ______________
8. Compute R_1, R_2, R_3, and R_4 using the voltage drops and currents measured in Steps 3 and 4. ______________
9. Compute R_T using the resistance values computed in Step 8. ______________

JOB SHEET #4

10. Return equipment and materials to their proper storage area.

    (NOTE: The following questions may be discussed in class:

    a. Did the value of R_T computed in Step 7 differ from Step 9?

       Explain.

    b. Why does the resistance computed using the voltage drop and current differ from the color-coded value?

    c. How much difference do you think you can permit between the computed and the color-coded values of a resistor? Why?

    d. Does the total power (IE) equal the total power computed in Step 5? Explain any differences.)

CIRCUITRY
UNIT III

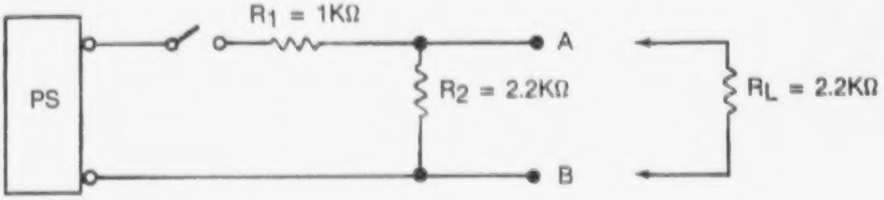
JOB SHEET #5 — CONSTRUCT A VOLTAGE DIVIDER AND ANALYZE ITS FUNCTION

A. Equipment and materials needed

1. DC power supply
2. Multimeter
3. One 1000 ohm and two 2200 ohm resistors, ½W or more

B. Procedure

1. Connect the resistors in series with the power supply as shown in the following schematic.



2. Adjust the power supply to 20V.
3. Close the switch and measure and record V_{R_2} and V_{R_1}.______________ ______________
4. Connect the load across points A and B.
5. Read and record the voltage across R_1 and across R_2 with the load connected.______________
6. Explain why V_{R_1} changed when the load was connected and explain the direction of the change.______________ ______________
7. Explain the differences observed in V_2 with and without the load.______________ ______________

JOB SHEET #5

8. Return equipment and materials to their proper storage area.

   (NOTE: The following questions may be discussed in class:

   a. Do series resistors cause voltage changes when load currents change?

   b. When the load is connected does the power supply "see" a series circuit or a series-parallel circuit?)

CIRCUITRY
UNIT III

NAME ______________________

TEST

1. Match the terms on the right with their correct definitions.

______a. A circuit where the same current passes through each component

______b. An overcurrent protective device with an element that melts and opens the circuit when overheated; this device must be replaced

______c. A circuit with no available path for current to flow (infinite resistance)

______d. A system of conductors through which an electric current is intended to flow

______e. A device designed to switch open a circuit automatically when a current overload exists; this device may be reset

______f. An electronic circuit which provides more than one path (or branch) for current to flow

______g. Applying Ohm's law and other rules to determine the effect of certain parameters on circuit variables

______h. A circuit that contains some components in series and some in parallel

______i. A junction point in a circuit at which current divides into separate branches, or reunites from separate branches

______j. Circuit originating from a main circuit, often one of many

______k. Circuit that bypasses another circuit or device, especially a low-resistance bypass for an ammeter circuit

______l. Unit of measure for power

______m. The rate of doing work

______n. Amount of energy used in a specified time

1. Branch circuit
2. Circuit breaker
3. Open circuit
4. Circuit analysis
5. Series circuit
6. Work
7. Series-parallel circuit
8. Shunt
9. Circuit
10. Power
11. Parallel circuit
12. Node
13. Fuse
14. Watt

TEST

2. Select true statements concerning voltage in a series circuit by placing an "X" in the blanks preceding the true statement.

______a. The sum of the voltages measured across each resistor will equal the applied voltage.

______b. The voltage measured across each resistor can be calculated by using Kirchhoff's voltage law when both total current and resistance are known.

______c. Voltages added in series can be either series-aiding or series-opposing.

3. Complete the following list of statements concerning resistance in a series circuit by inserting the word(s) that best completes each statement.

a. The sum of the resistance (R_T) equals the ______________ resistance.

b. The resistance value of an unknown resistor in series can be calculated by using ______________ law and ______________ law.

4. Select true statements concerning current in a series circuit by placing an "X" in the blanks preceding the true statements.

______a. The current through each resistor is equal to the total current (I_T).

______b. Total current can be calculated using Ohm's law from any voltage drop and resistance value.

5. Select true statements concerning voltage in a parallel circuit by placing an "X" in the blanks preceding the true statements.

______a. The voltage varies across parallel branches.

______b. Branch elements in a parallel circuit work independently of each other.

______c. The voltage is the same across parallel branches.

6. Complete the following list of statements concerning resistances in parallel by inserting the word(s) which best completes each statement.

a. ______________ is used to determine total resistance if current is known.

b. If current is not known, the ______________ resistive formula is used to compute total resistance.

c. Equal branch method is used if resistors of equal value (R) are connected in ______________.

d. Unequal branch method is used when two resistors (R_1 and R_2 of ______________ value are connected in parallel.

e. ______________ — The total resistance of parallel resistors is always less than the resistance of any one branch.

TEST

7. Select true statements concerning current in a parallel circuit by placing an "X" in the blanks preceding the true statements.

   ______a. A part of the total circuit current flows through each branch.

   ______b. The current of each branch equals the voltage multiplied by the resistance of the branch.

   ______c. The main line current (I_T) equals the sum of the branch currents ($I_1 + I_2 + I_3 + \ldots$).

8. Complete the following list of statements concerning voltage in a series-parallel circuit by inserting the word(s) which best complete(s) each statement.

   a. The voltage drop across any resistance in a series string is equal to the resistance ______________ by the current of the string.

   b. The total of the voltage drops in a series string equals the ______________ across the entire string.

9. Arrange in order the steps to simplify a series-parallel circuit by indicating the first step as 1, the second step as 2, and so on for each procedure.

   ______a. Redraw the circuit using a single resistor to represent each equivalent resistance.

   ______b. Identify series resistors.

   ______c. Combine all equivalent resistances and series resistances to determine total resistance.

   ______d. Identify all parallel groups of resistors.

   ______e. Reduce each parallel group to an equivalent resistance, R_{EQ}.

10. Select true statements concerning current in a series-parallel circuit by placing an "X" in the blanks preceding the true statements.

    ______a. Current in each branch of a series-parallel circuit equals the voltage across the branch multiplied by the total resistance in the branch.

    ______b. Total line current equals the sum of the currents in each branch.

    ______c. Current in each branch of a series-parallel circuit equals the voltage across the branch divided by the total resistance in the branch.

11. Complete the following list of statements concerning characteristics of electrical power by inserting the word(s) which best completes each statement.

    a. The fundamental unit of measure for electrical power is the watt (W) and may be measured with an instrument called a ______________.

    b. Electrical power is the time rate at which a charge is moved by ______________.

TEST

c. Power (P) in an electrical circuit may be calculated by using ____________ law, expressed by three basic formulas:

$P \text{ (in watts)} = E \text{ (volts) } I \text{ (amperes)}$

$P \text{ (in watts)} = I^2 \text{ (amperes) } R \text{ (ohms)}$

$P \text{ (in watts)} = \frac{E^2 \text{ (volts)}}{R \text{ (volts)}}$

d. Power is dissipated in resistance in the form of ____________ and is made evident by a voltage drop across the resistance.

12. Select true statements concerning functions of a voltage divider by placing an "X" in the blanks preceding the true statements.

_____a. A voltage divider does not allow tapping off of different voltages for various applications.

_____b. Chassis ground is often used as the zero reference point.

_____c. Tapped voltages may be either positive or negative.

_____d. A load is connected in parallel with the resistor from which the voltage is tapped.

_____e. If the load draws appreciable current, the voltage division differs from the no-load condition.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Determine total voltage in a series circuit. (Assignment Sheet #1)

14. Determine voltage drops across resistances. (Assignment Sheet #2)

15. Determine the total resistance in a series circuit. (Assignment Sheet #3)

16. Determine current in a series circuit. (Assignment Sheet #4)

17. Determine unknown circuit values. (Assignment Sheet #5)

18. Determine unknown values in a resistive series circuit. (Assignment Sheet #6)

19. Compute the power dissipated in a resistive series circuit. (Assignment Sheet #7)

20. Calculate current and voltage in parallel circuits. (Assignment Sheet #8)

21. Calculate resistance in parallel circuits. (Assignment Sheet #9)

22. Calculate power in parallel circuits. (Assignment Sheet #10)

23. Calculate various values in parallel circuits. (Assignment Sheet #11)

TEST

24. Trace current flow in series-parallel circuits. (Assignment Sheet #12)

25. Perform exercises in circuit reduction. (Assignment Sheet #13)

26. Solve for total resistance. (Assignment Sheet #14)

27. Solve for total current. (Assignment Sheet #15)

28. Solve for total voltage. (Assignment Sheet #16)

29. Solve for branch voltages and currents in series-parallel circuits. (Assignment Sheet #17)

30. Solve for multiple values of voltages and current. (Assignment Sheet #18)

31. Answer questions regarding opens and shorts in series-parallel circuits. (Assignment Sheet #19)

32. Answer questions about grounds and voltage polarity. (Assignment Sheet #20)

33. Analyze no-load and load circuits. (Assignment Sheet #21)

34. Demonstrate the ability to:

    a. Verify Ohm's law. (Job Sheet #1)

    b. Analyze a series circuit. (Job Sheet #2)

    c. Measure voltage, current, and resistance in a parallel circuit. (Job Sheet #3)

    d. Analyze a series-parallel circuit. (Job Sheet #4)

    e. Construct a voltage divider and analyze its function. (Job Sheet #5)

CIRCUITRY
UNIT III

ANSWERS TO TEST

1. a. 5 h. 7
   b. 13 i. 12
   c. 3 j. 1
   d. 9 k. 8
   e. 2 l. 14
   f. 11 m. 10
   g. 4 n. 6

2. a, c

3. a. Total
   b. Ohm's, Kirchhoff's

4. a, b

5. b, c

6. a. Ohm's law
   b. Reciprocal
   c. Parallel
   d. Unequal
   e. Parallel rule

7. a, c

8. a. Multiplied
   b. Voltage

9. a. 4
   b. 1
   c. 5
   d. 2
   e. 3

10. b, c

11. a. Wattmeter
    b. Voltage
    c. Watt's
    d. Heat

12. b, c, d, e

13.-33. Evaluated to the satisfaction of the instructor

34. Performance skills evaluated to the satisfaction of the instructor

INTRODUCTION TO AC
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to apply theoretical knowledge related to alternating current, measure alternating current, and convert from one AC measurement to another AC measurement. Competencies will be demonstrated by correctly performing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to introduction to AC with their correct definitions.
2. Select true statements concerning principles of inductance.
3. Select true statements concerning principles of capacitance.
4. Match types of transformers with their correct descriptions.
5. Calculate the power in three-phase circuits.
6. Arrange in order the steps for identifying three-phase transformer connections.
7. Solve problems converting from one AC measurement to another AC measurement.
8. Select true statements concerning phase shifting.
9. Discuss the relationship between time and frequency.
10. Identify common types of filters.

OBJECTIVE SHEET

11. Complete a list of statements concerning configurations of filters.

12. Identify types of single-phase transformer connections.

13. Demonstrate the ability to:

    a. Measure alternating current voltages using a multimeter. (Job Sheet #1)

    b. Measure alternating current using a multimeter. (Job Sheet #2)

    c. Determine the configuration of a multiple-winding transformer. (Job Sheet #3)

INTRODUCTION TO AC
UNIT IV

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Use a triggered oscilloscope to show three-phase AC power. Set the trigger to line and scope each phase to show the 120° phase relationship.

   2. Using an oscilloscope, demonstrate transformer frequency response.

   3. Find examples of various types of capacitors and show them to students.

   4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Suggested activities

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

C. Information sheet

D. Transparency masters

  1. TM 1 — Three-Phase Voltage, Current, and Power
  2. TM 2 — Procedure for Identifying Three-Phase Connections
  3. TM 3 — Procedure for Identifying Three-Phase Connections (Continued)

E. Job sheets

  1. Job Sheet #1 — Measure Alternating Current Voltages Using a Multimeter
  2. Job Sheet #2 — Measure Alternating Current Using a Multimeter
  3. Job Sheet #3 — Determine the Configuration of a Multiple-Winding Transformer

F. Test

G. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

(NOTE: The following is a list of references used in completing this unit.)

A. Grob, Bernard. *Basic Electronics*. New York: McGraw-Hill Book Company.

B. Mileaf, Harry. *Electricity One-Seven*. Hasbouck Heights, NJ: Hayden Book Company, Inc.

C. *New Mexico Vocational Industrial Safety Guide*. Santa Fe, NM: New Mexico State Department of Education.

D. Robertson, L. Paul. *Basic Electronics I (Revised Edition)*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

E. Siebert, Leo N. *Introduction to Industrial Electricity-Electronics*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1981.

INTRODUCTION TO AC
UNIT IV

INFORMATION SHEET

I. **Terms and definitions**

A. AC — Abbreviation for alternating current

B. Bleeder resistor — A resistor that is placed in parallel with a capacitor in order to provide a discharge path for the capacitor when the power supply is turned off

C. Capacitance — Property of a capacitor that opposes any change in voltage

D. Capacitor — Device used to store electrical charge

E. Capacitor tester — An instrument that measures capacitance in leakage current

F. Choke — A coil of wire wound around an iron core or a form of insulating material a number of times

G. Counter electromotive force (CEMF) — Voltage developed in an inductor which is opposite that of the applied voltage at every instant

H. Cycle — One complete set of values for a repetitive wave form

I. Dielectric — Insulating substance between plates of a capacitor

J. Electrolytic capacitor — Capacitor that must be connected in only one direction, observing polarity

K. Electromotive force (EMF) — Force or voltage that causes current to flow through a device

L. Farad — Unit of measure of capacitance

M. Filter — A device that reduces rapid variations in voltage or current by restricting variations from the circuit, bypassing variations from the circuit or slowing rapid variations to a gradual change

N. Frequency — The number of cycles per second for a waveform with periodic variations

O. Henry — Unit of measure of inductance

P. Hertz — Unit of frequency; one Hertz equals one cycle per second

INFORMATION SHEET

Q. Inductance — Property of an inductor that opposes any change in current flow

R. Inductor — Device used to concentrate magnetic lines of force

S. Induction — Production of an electric charge or magnetic field in a substance by an electric source, magnet, or magnetic field

T. Insulation — A substance that prohibits flow of electricity

U. Lag or lead angle — The relative displacement between voltage and current waveforms measured in degrees; one cycle is 360°

V. Leakage current — Undesirable current flow between capacitor plates due to inability of dielectric material to restrict that flow

W. Period — The amount of time for one cycle

X. Phase — Source of AC power; a relationship between time and AC wave form or between AC wave forms

Y. Reactance — Measure of AC opposition offered by components such as capacitors and inductors; measured in units of ohms

Z. Ripple — Variations in DC voltage

AA. Self-inductance — Conductor's ability to induce voltage in itself when current changes

BB. Tank circuit — An inductor and capacitor in parallel

CC. Time constant — Time required for a capacitor or inductor to change by 63% after a sudden rise or fall in voltage or current

II. **Principles of inductance**

A. Self-inductance or inductance is the ability of a conductor to produce an induced voltage when current varies.

B. Inductors resist rapid changes in the current flowing through them, and allows DC current to flow.

C. Mutual inductance is the ability of a conductor to induce a voltage in another nearby conductor.

D. Current lags voltage by 90° in a purely inductive circuit.

INFORMATION SHEET

III. Principles of capacitance

A. Capacitors have the ability to store a charge.

B. Capacitors are two conductors separated by an insulator.

C. Voltage applied to a capacitor causes electron build up on the negative conductor which will in turn force electrons on the positive conductor to be repelled.

D. Voltage lags current by 90° in a purely capacitive circuit.

IV. Types of transformers

A. Voltage transformer — Step-down transformer used to reduce high voltage by a specified ratio

B. Current transformer — Step-down transformer used to reduce high current and provide isolation from high voltages; provides a fraction of current to gauge value of total current

C. Air-core transformer — Transformer without an iron or metal core; usually applied to low power, high frequency applications

D. Autotransformer — Transformer whose primary and secondary windings are of a common core and share a common connection

(CAUTION: This transformer does not have an isolated secondary.)

E. Iron-core transformer — Transformer having metal core usually made of laminations of iron or steel; usually applied to low frequency, high power applications

F. Toroidal transformer — Transformer having a ring-shaped core around which windings are wrapped

G. Isolation transformer — Transformer used to isolate circuits from a common ground, from direct current potentials, or to improve power transfer by impedance matching improvement, often providing no change in voltage

(CAUTION: An isolation transformer should be used between test equipment to avoid possible electrical shock.)

H. Variable AC transformer (Variac) — Transformer which can be varied while in operation

(CAUTION: This transformer does not have an isolated secondary.)

INFORMATION SHEET

I. Step-down transformer — Transformer used to reduce voltage while increasing current capability above that of the source

J. Step-up transformer — Transformer used to increase voltage, while decreasing current capability of source

(NOTE: Because of the laws of energy conservation, step-up and step-down transformers always decrease current for voltage or vise versa as measured from the primary to the secondary.)

K. Spark coil — High voltage transformer, usually an autotransformer; often used to develop high voltage ignition for gasoline engines and gas firing devices

L. Booster transformer — Additional transformer placed in a transmission or distribution line to boost voltage to an acceptable level from a reduced level caused by line length

V. **Power in three-phase circuits** (Transparency 1)

A. Delta — Voltage across each load member is the full-line voltage; amperage in each member is $\sqrt{3}$ × line amps or 1.732 × amps

B. Wye — Amperage in each member is full-line amperage; voltage across each member is $\sqrt{3}$ × line volts or 1.732 × line volts

(NOTE: To find the power in delta or wye circuits, use the formula $P = I \times \sqrt{3} \times E$.)

Example: A three-phase circuit has 10 amperes measured on each line. The voltage is 480 volts. It is not known whether the circuit is delta or wye. What is the power of the circuit?

Solution: $P = I \times \sqrt{3} \times E$

$= 10 \times 480 \times 1.732$

$= 8{,}314$ VA

$= 8.3$ kVA

VI. **Steps for identifying three-phase transformer connections** (Transparencies 2 and 3)

A. Label circuit components and connection points

B. Resketch circuit so that connections along the same wire are all at one point, looping wires as necessary and avoiding crossing wires as much as possible

INFORMATION SHEET

C. Resketch circuit, omitting any wire that does not go from one device to another

D. Rearrange components in one or more sketches until the configuration is determined

(NOTE: This procedure is presented to show how the names relate to the actual configurations and to give a procedure to use until configurations become readily apparent merely upon observation.)

VII. Formulas for converting from one AC measurement to another AC measurement

(NOTE: Meters automatically measure effective voltage, amperage, or power, and conversion is not necessary. Oscilloscopes show peak-to-peak values; however, components are sometimes rated at maximum instantaneous current or voltage rather than at an effective value. For these reasons, it is sometimes necessary to convert values.)

A. Convert from a P-P voltage to a P voltage — Use the formula $P = \frac{P\text{-}P}{2}$

(NOTE: Peak voltage is one-half of the P-P voltage.)

Example: A voltage display on an oscilloscope indicates a P-P voltage of 340 volts

$$\begin{aligned} P &= \frac{P\text{-}P}{2} \\ &= \frac{340\ V}{2} \\ &= 170\ V \end{aligned}$$

B. Convert from P to P-P voltage — Use the formula $P\text{-}P = P \times 2$

(NOTE: P-P voltage is twice the amount of peak voltage.)

Example: Using the P voltage above of 170 volts

$$\begin{aligned} P\text{-}P &= P \times 2 \\ &= 170\ V \times 2 \\ &= 340\ V \end{aligned}$$

INFORMATION SHEET

C. Convert P-P voltage to effective voltage — Use the formula Eff = P × .707

(NOTE: Effective voltage is the root-mean-square value of the peak voltage. Root mean square is the most common method of specifying the amount of sine wave voltage which is 70.7% of the peak value.)

Example: Using the value above of 340 volts, P-P must be converted to a P voltage as in A; then this P value is used to convert to effective voltage.

$$\begin{aligned} \text{Eff} &= \text{P} \times .707 \\ &= 170\text{ V} \times .707 \\ &= 120\text{ V} \end{aligned}$$

D. Convert effective voltage to P-P voltage — Use the formula $P = \text{Eff} \times \sqrt{2}$

Example: Using the value above of 120 volts, first calculate for the P voltage, then for P-P voltage.

$$\begin{aligned} \text{P} &= \text{Eff} \times \sqrt{2} \\ &= 120\text{ V} \times \sqrt{2} \\ &= 169.7\text{ V or } 170\text{ V} \end{aligned}$$

$$\begin{aligned} \text{P-P} &= \text{P} \times 2 \text{ or } 170\text{ V} \times 2 \\ &= 340\text{ V} \end{aligned}$$

E. Convert P-P voltage to average voltage — Use the formula AVG = P × .636

(NOTE: Average voltage is the average of one alternation or a value of .636 of the peak voltage.)

Example: Using the P-P value above of 340 volts, find the P value which is 170 volts. Then calculate for the average voltage.

$$\begin{aligned} \text{Ave} &= \text{P} \times .636 \\ &= 170\text{ V} \times .636 \\ &= 108\text{ V} \end{aligned}$$

INFORMATION SHEET

F. Convert the average voltage to a P-P value — Use the formula $P = AVG \times 1.572$

Example: Use the average value above of 108 volts

$$P = AVG \times 1.572$$

$$= 108\ V \times 1.572$$

$$= 170\ V$$

$$P\text{-}P = P \times 2$$

$$= 170\ V \times 2$$

$$= 340\ V$$

VIII. Phase shifting

(NOTE: The time relationship between alternating voltages and current can be represented by the phase angle indicated in degrees.)

A. A purely resistive circuit has 0 phase angle.

B. In a purely capacitive circuit, current leads voltage by a phase angle of 90°.

C. In a purely inductive circuit, voltage leads current by a phase angle of 90°.

IX. Relationship between time and frequency

(NOTE: Frequency measured in hertz or cycles per second (cps) is inversely proportional to time.)

A. $T = 1 / \text{Frequency} = 1 / f$

Example: $f = 10K\ Hz$ $\quad$ $\text{Time} = 1 / 10\,000\ Hz = .1ms$

B. $f = 1 / \text{Time} = 1 / s$

Example: $s = 1$ micro second $\quad$ $f = 1 / .000001 = 1M\ Hz$

C. $T = (\Theta / 360) \times 1 / f$

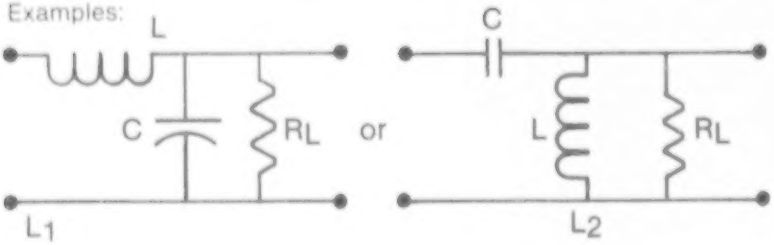
Example: $\Theta = 60°$ and $f = 60\ Hz$
$T = (60 / 360) * (1 / 60) = 2.77ms$

INFORMATION SHEET

X. **Common types of filters**

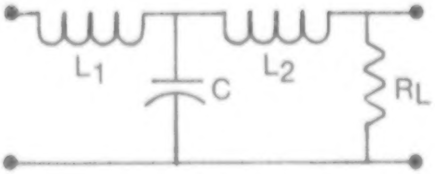
A. L-filter

Examples:



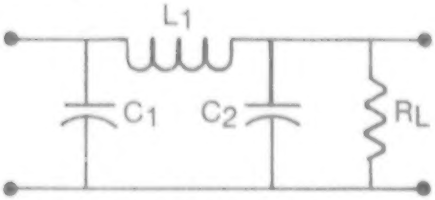
B. T-filter

Example:



C. π-filter

Example:



XI. **Configurations of filters**

A. High-pass

1. Coupling capacitance in series with the load
2. Choke inductance in parallel with the load

B. Low-pass

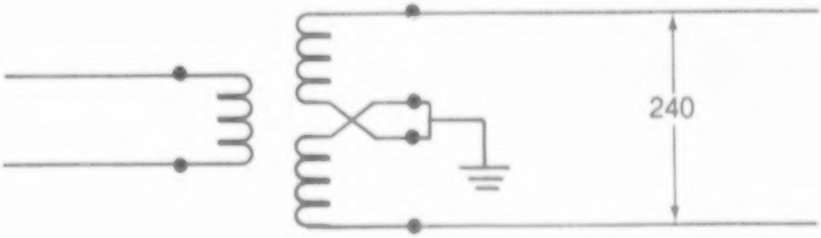
1. Choke inductance in series with the load
2. Bypass capacitance in parallel with the load

INFORMATION SHEET

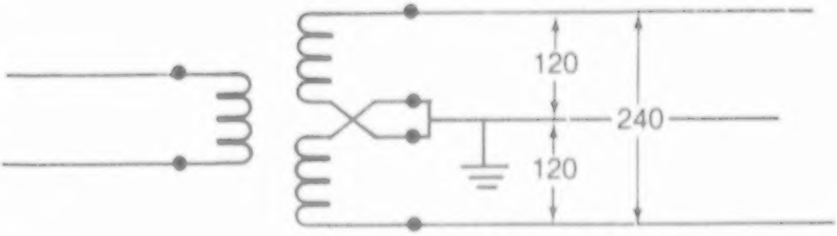
XII. Types of single-phase transformer connections

(NOTE: Transformers shown are standard power distribution types with two 120-volt secondary windings. A single winding or two in parallel will produce 120 volts. Both windings in series will produce 240 volts. Grounded terminals produce the "neutral conductor.")

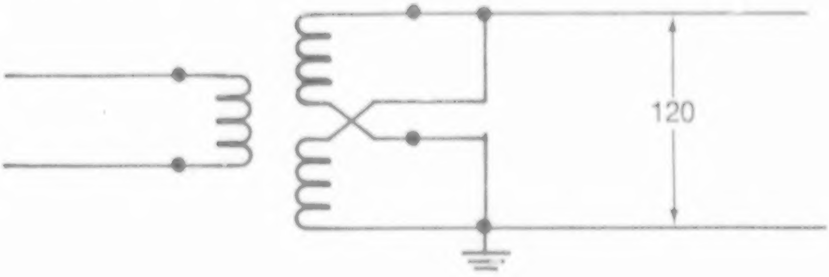
A. 240 volts, two-wire



B. 120/240 volts, three-wire

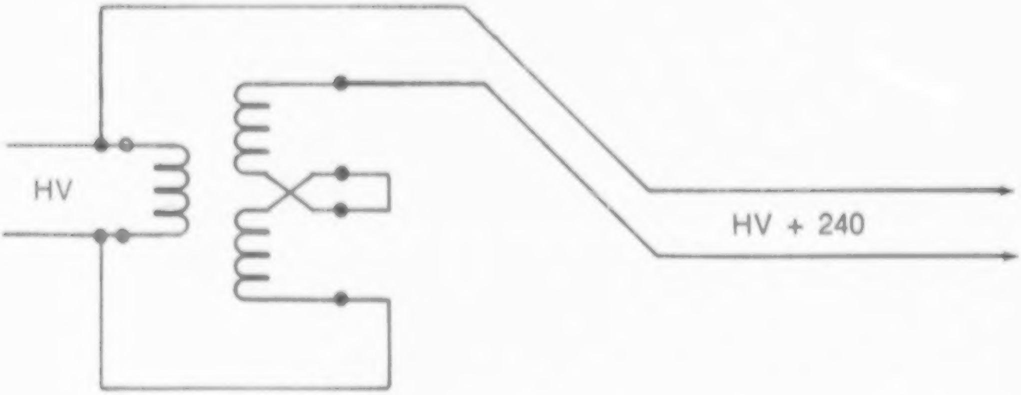


C. 120 volts, two-wire

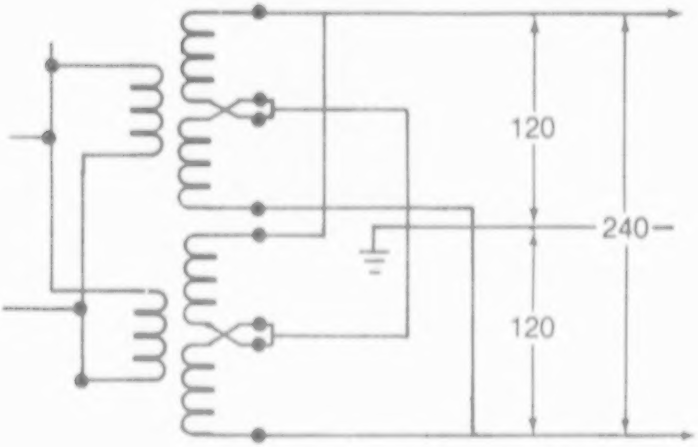


INFORMATION SHEET

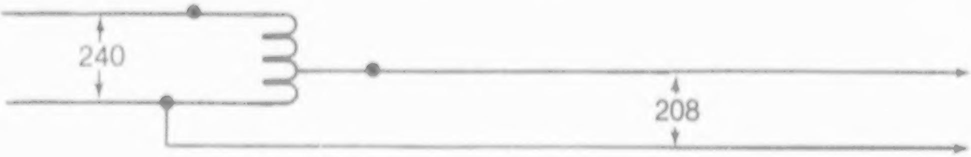
D. High voltage, boosted by 240 volts



E. 120/240 volts, three-wire with additional power capacity of two transformers

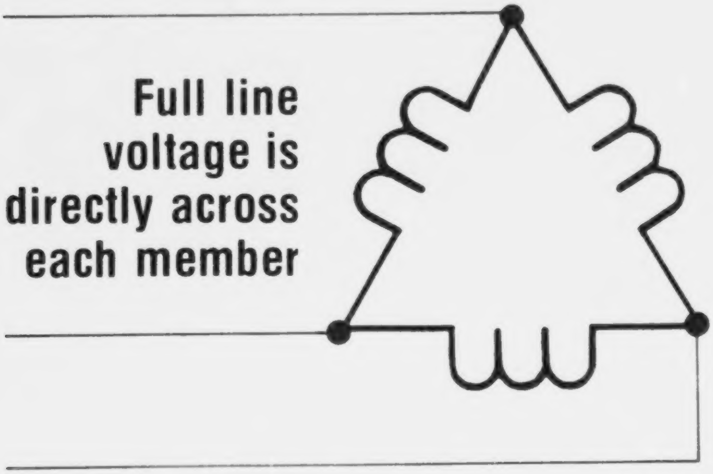


F. 208 volts, two-wire from 240 volt through autotransformer



Three-Phase Voltage, Current, and Power

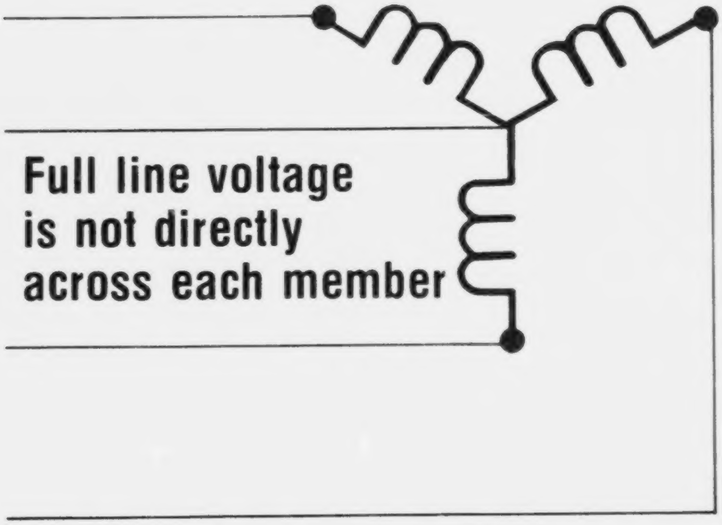
Delta



Full line voltage is directly across each member

Full-line amperage is not through each member

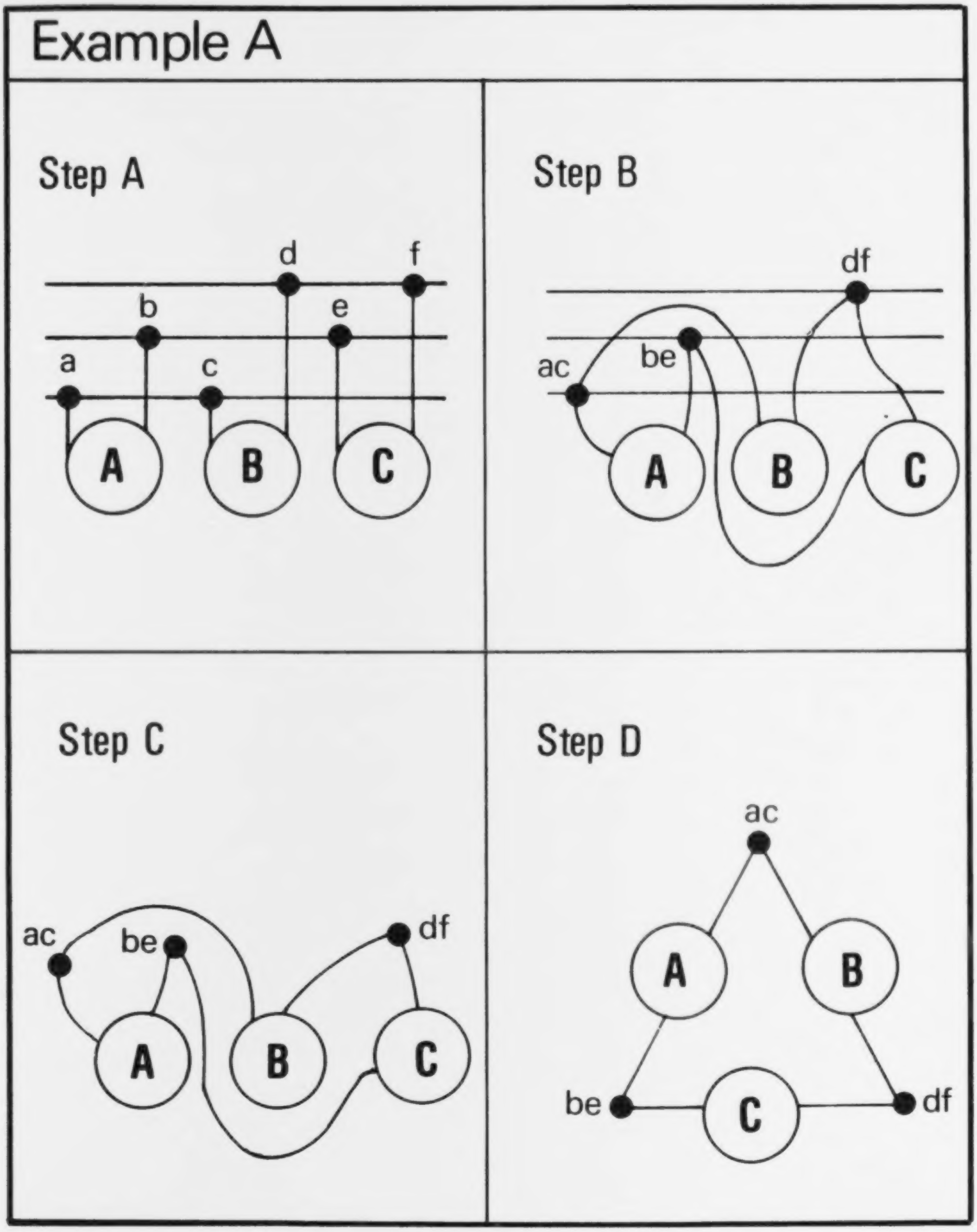
Wye



Full-line current is through each member

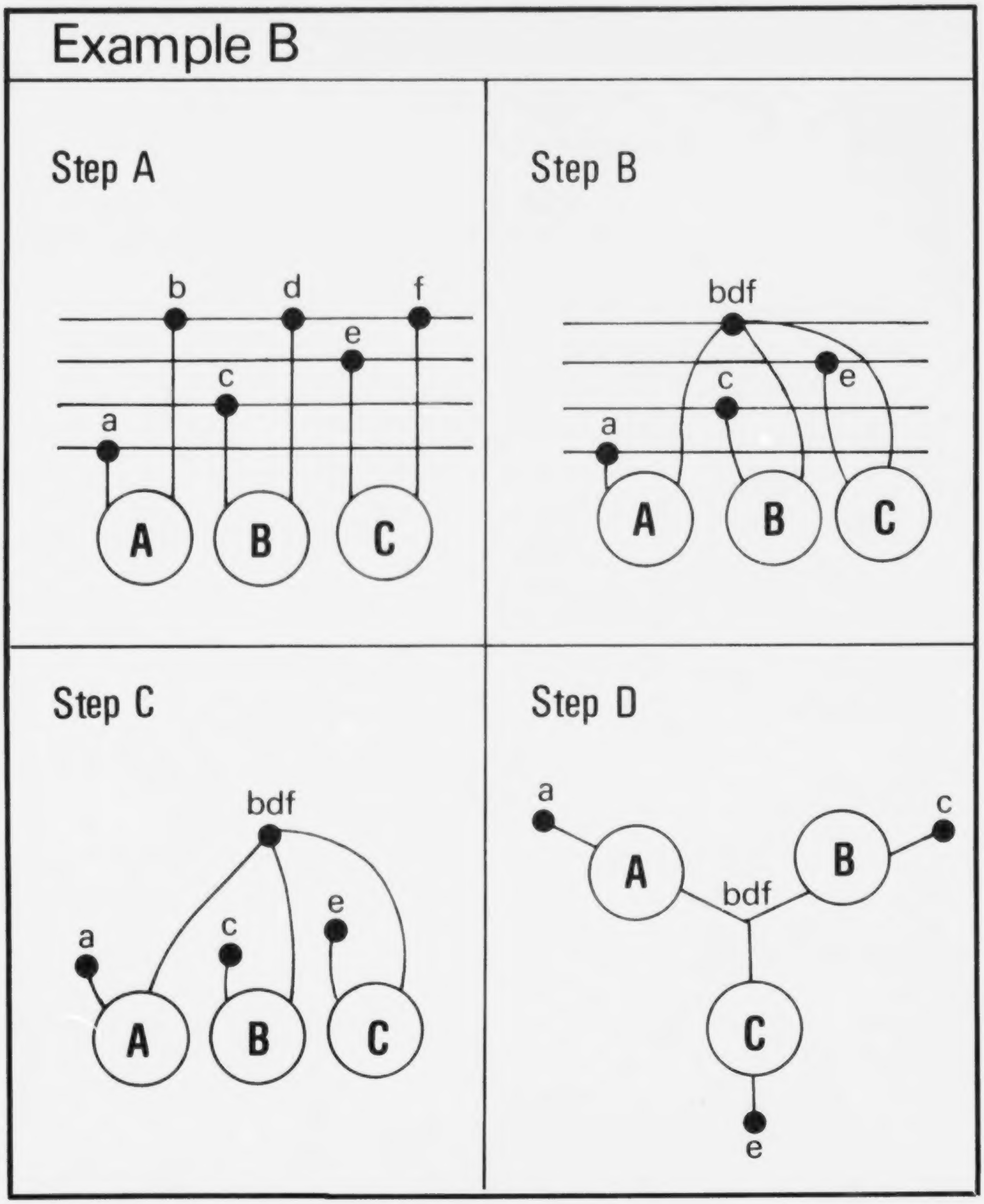
Full line voltage is not directly across each member

Procedure for Identifying Three-Phase Connections


Example A
Step A
d
f
b
e
a
c
A
B
C
Step B
df
ac
be
A
B
C
Step C
ac
be
df
A
B
C
Step D
ac
A
B
be
C
df

Procedure for Identifying Three-Phase Connections

(Continued)



Example B

Step A

Step B

Step C

Step D

b
d
f
e
c
a
A
B
C
bdf
c
e
a
A
B
C
bdf
a
c
e
A
B
C
a
c
A
B
bdf
C
e

INTRODUCTION TO AC
UNIT IV

JOB SHEET #1 — MEASURE ALTERNATING CURRENT VOLTAGES USING A MULTIMETER

A. Equipment and materials needed

1. Multimeter with test leads

2. Alternate current power sources

   Examples: 24-volt transformer, rheostat

B. Procedure

1. Set multimeter controls to measure AC volts.

2. Measure "line voltage" of power receptacle at the work bench. (See diagram below.)

   (CAUTION: 120 volts can cause injury or death. Do not touch the metal parts of the test leads while measuring.)

3. Record the readings below.

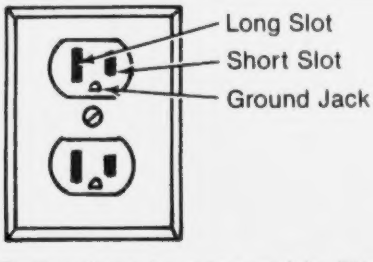
   a. Voltage between slotted jacks ______________________

   b. Voltage between longest slotted jack and ground jack ______________________

   ____

   c. Voltage between short slotted jack and ground jack ______________________

   ____



   (NOTE: If voltage is measured in Step 3b, the receptacle is wired incorrectly. Notify your instructor.)

4. Attach the equipment given to you by the instructor to specified power source.

JOB SHEET #1

5. Measure output voltages.

6. Record data below for those devices specified by your instructor.

   a. Voltage at setting specified by instructor ______________________

   b. Transformer output voltage ______________________

   c. Rheostat output voltage at setting specified by instructor __________

   ____

   d. Other devices or source of AC voltage

      1) Name ______________________

      2) Voltage ______________________

      (NOTE: Show your results to the instructor.)

7. Return equipment and materials to their proper storage area.

INTRODUCTION TO AC
UNIT IV

JOB SHEET #2 — MEASURE ALTERNATING CURRENT USING A MULTIMETER

A. Equipment and materials needed

1. Multimeter with test leads
2. Lamp base — 120 VAC
3. Lamp — 40 to 150 watts
4. Lamp cord with 120 volt plug

B. Procedure

1. Connect lamp, multimeter, and plug in series.

   (NOTE: Have instructor check your circuit.)

2. Set multimeter for AC amperage measurement.
3. Plug circuit into 120 VAC receptacle, and measure the current; record measurement below.

   Lamp current = ________________ amps

4. Multiply amperage reading obtained in this job sheet by the voltage reading obtained in Job Sheet #1, 3a.; record below.

   Amps × volts = ________________ watts

5. Return equipment and materials to their proper storage area.

INTRODUCTION TO AC
UNIT IV

JOB SHEET #3 — DETERMINE THE CONFIGURATION OF A MULTIPLE-WINDING TRANSFORMER

A. Equipment and materials needed

1. Multimeter
2. DC power supply, or DC source (battery) — 12 to 24 volts, with test leads
3. Variable AC supply — 60 Hz, from 20 to 120 volts, with test leads
4. Multiple winding transformer with diagram — 60 Hz, 120- to 240-volt primary, step-down secondaries, wire leads attached
5. Wire markers (numbered tape markers) — At least half as many as the number of transformer connections

B. Procedure

1. Use wire markers to mark each transformer lead wire.

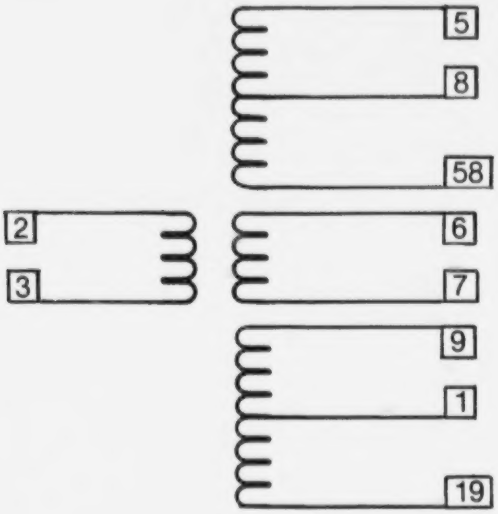
   (NOTE: Use a number "2" and a number "10" to make 210, etc. Each wire should have a different number or a different pair of numbers.)

2. Use the ohmmeter to identify which wires are interconnected.

JOB SHEET #3

3. Record the numbers in groups as shown in Figure 1

FIGURE 1



4. Connect the transformer to the AC supply or variac by connecting it to the group that has only one pair, the heaviest insulation, is color-coded black, or is the most removed from the other leads.

   (NOTE: This should be the primary input. Ask your instructor to check your work before proceeding to the next step.)

5. Separate the wires so that their leads do not touch.

6. Turn the AC supply output control down to the minimum.

7. Turn on the power, adjusting the AC supply output for 20 volts.

   (NOTE: Use the voltmeter if the supply does not have a panel meter.)

8. Use voltmeter to measure between wires within each group.

9. If any pair produces a reading of more than 20 volts, reconnect the power supply to that pair.

10. Remeasure and record the voltage between each pair with each group as shown in Figure 1.

JOB SHEET #3

11. Sketch each group from voltage readings.

    (NOTE: The two having the highest readings are the outside ends of the windings; other measurements should be parts of that total voltage.)

12. Disconnect the AC supply.

13. Connect one primary lead to the DC supply.

14. Answer the following questions:

    a. Do transformers operate on DC power?

    ____

    ____

    b. If AC is constantly changing, is it significant to assign a polarity relationship to transformer windings?

    ____

    ____

15. Connect the voltmeter between a pair of leads representing the ends of a winding.

16. Set the controls for 24 volts DC.

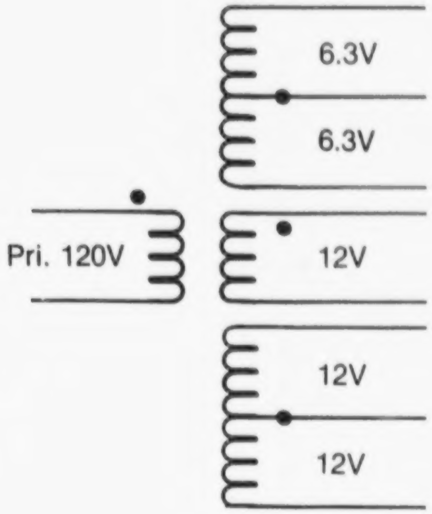
17. Turn on the DC supply and briefly touch the remaining transformer primary lead to the other DC supply output terminal making contact for only a split second while watching the voltmeter.

JOB SHEET #3

18. If the voltmeter deflects toward upper scale (positive flash for digital meters), return to the sketches you made in Step 11, and draw in and mark with a large dot next to the number, the transformer lead connected to the positive voltmeter lead as shown in Figure 2.

    (NOTE: These dots are referred to as *phasing dots* and are sometimes seen on schematics.)

    FIGURE 2



19. Using the Step 11 sketches, draw and mark with a large dot, the transformer lead connected to the negative voltmeter lead, if the meter indication tends to go off scale or negative.
20. Continue with Steps 17, 18, and 19 for each set of secondary end leads.
21. Using the Step 11 sketches, draw in the transformer primary.
22. Mark a large dot next to the lead connected to the positive terminal of the DC supply.

JOB SHEET #3

23. Resketch the transformer making all dot-marked leads at the top of the windings as in Figure 2.

24. Multiply each AC voltage reading by six, because the input was only 20 volts in the test, or 1/6 of 120 volts.

    (NOTE: If the transformer has a 240-volt primary, multiply each voltage reading by twelve.)

25. Record the voltages on the new transformer sketch.

    (NOTE: Show your sketch to the instructor.)

26. Return equipment and materials to their proper storage area.

INTRODUCTION TO AC
UNIT IV

NAME ____________________

TEST

1. Match the terms on the right with their correct definitions.

(NOTE: Answers to questions a.-k. appear on this page.)

_____a. Source of AC power; relationship between time and AC waveform, or between AC waveforms

_____b. A device that reduces rapid variations in voltage or current by restricting variations from the circuit, bypassing variations from the circuit or slowing rapid variations to gradual changes

_____c. Measure of AC opposition offered by components such as capacitors and inductors; measured in units of ohms

_____d. The relative displacement between voltage and current waveforms measured in degrees; one cycle is 360 degrees

_____e. Time required for a capacitor or inductor to change by 63% after a sudden rise or fall in voltage or current

_____f. Device used to concentrate magnetic lines of force

_____g. Property of an inductor that opposes any change in current flow

_____h. Production of an electric charge or magnetic field in a substance by an electrical source, magnet, or magnetic field

_____i. Conductor's ability to induce voltage in itself when current changes

_____j. Force or voltage that causes current to flow through a device

_____k. Voltage developed in an inductor which is opposite that of the applied voltage at every instant

1. Time constant
2. Lag or lead angle
3. Inductance
4. Self-inductance
5. Inductor
6. Electromotive force
7. Filter
8. Reactance
9. Induction
10. Counter electromotive force
11. Phase

TEST

(NOTE: Answers to questions l.-cc. appear on this page.)

______l. A coil of wire wound around an iron core or form of insulating material a number of times

______m. Unit of measure of inductance

______n. A substance that prohibits flow of electricity

______o. Insulating substance between plates of a capacitor

______p. Undesirable current flow between capacitor plates due to inability of dielectric material to restrict that flow

______q. An instrument that measures capacitance and leakage in current

______r. Capacitor that must be connected in only one direction, observing polarity

______s. Unit of measure of capacitance

______t. Variations in the DC voltage

______u. A resistor that is placed in parallel with a capacitor in order to provide a discharge path for the capacitor when the power supply is turned off

______v. Abbreviation for alternating current

______w. The number of cycles per second for a waveform with periodic variations

______x. Property of a capacitor that opposes any change in voltage

______y. One complete set of values for a repetitive waveform

______z. Unit of frequency; one of these equals one cycle per second

______aa. Device used to store electrical charge

______bb. The amount of time for one cycle

______cc. An inductor and capacitor in parallel

12. Choke
13. Dielectric
14. Henry
15. Insulation
16. Electrolytic capacitor
17. Farad
18. Bleeder resistor
19. Capacitor tester
20. Tank circuit
21. Leakage current
22. Period
23. Capacitance
24. Hertz
25. AC
26. Capacitor
27. Cycle
28. Frequency
29. Ripple

TEST

2. Select true statements concerning principles of inductance by placing an "X" in the blanks preceding true statements.

   ______a. Self-inductance or inductance is the ability of a conductor to produce an induced voltage when current varies.

   ______b. Inductors resist rapid changes in the current flowing through them, and allows DC current to flow.

   ______c. Mutual inductance is the ability of a conductor to induce a voltage in another nearby conductor.

   ______d. Voltage lags current by 90° in a purely inductive circuit.

3. Select true statements concerning principles of capacitance by placing an "X" in the blanks preceding true statements.

   ______a. Capacitors have the ability to store a charge.

   ______b. Capacitors are two conductors connected by an insulator.

   ______c. Voltage applied to a capacitor causes electron build up on the positive conductor which will in turn force electrons on the negative conductor to be repelled.

   ______d. Current lags voltage by 90° in a purely capacitive circuit

4. Match types of transformers on the right with their correct descriptions.

   ______a. Step-down transformer used to reduce high voltage by a specified ratio

   ______b. Step-down transformer used to reduce high current and provide isolation from high voltages; provides a fraction of current to gauge value of total current

   ______c. Transformer without an iron or metal core; usually applied to low power, high frequency applications

   ______d. Transformer whose primary and secondary windings are of a common core and share a common connection

   ______e. Transformer having metal core usually made of laminations of iron or steel; usually applied to low frequency, high power applications

   ______f. Transformer having a ring-shaped core around which windings are wrapped

   1. Air-core transformer
   2. Toroidal transformer
   3. Spark coil
   4. Booster transformer
   5. Step-down transformer
   6. Voltage transformer
   7. Step-up transformer
   8. Isolation transformer
   9. Iron-core transformer
   10. Current transformer
   11. Variac
   12. Autotransformer

TEST

_____g. Transformer used to isolate circuits from a common ground, from direct current potentials, or to improve power transfer by impedance matching improvement, often providing no change in voltage

_____h. Transformer which can be varied while in operation

_____i. Transformer used to reduce voltage while increasing current capability above that of the source

_____j. High voltage transformer, usually an autotransformer; often used to develop high voltage ignition for gasoline engines and gas firing devices

_____k. Additional transformer placed in a transmission or distribution line to boost voltage to an acceptable level from a reduced level caused by line length

_____l. Transformer used to increase voltage while decreasing current capability of source

5. Calculate the power in the three-phase circuits in the following problems.

   a. A delta connected transformer has 5 amps on each line. The voltage is 208 volts. What is the power of the circuit?

      Power = ____________________

TEST

b. A wye connected transformer has a voltage of 120 volts with 3 amps on each lead. What is the power of the circuit?

Power = ____________________

6. Arrange in order the steps in identifying three-phase transformer connections. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Rearrange components in one or more sketches until the configuration is determined.

_____b. Label circuit components and connection points.

_____c. Resketch circuit so that connections along the same wire are all at one point, looping wires as necessary, and avoiding crossing wires as much as possible.

_____d. Resketch circuit, omitting any wire that does not go from one device to another.

7. Solve problems converting from one AC measurement to another AC measurement.

a. A technician has measured an AC signal on the oscilloscope as 200 volts peak-to-peak. What is the effective voltage of that signal? ____________________

b. An electronic component is rated as being capable of operating at alternating voltages that average 30 volts. What peak-to-peak voltage is this equal to?

____

TEST

c. Positive alternations of an AC power source are found to be 150 volts in amplitude from zero-to-peak. What is the rms value of the original AC power source?

____

d. An ammeter measures 10 amperes rms in a motor circuit. What is the zero-to-peak value of the current?

____

8. Select true statements concerning phase shifting by placing an "X" in the blanks preceding the true statements.

______a. A purely resistive circuit has +90° phase angle.

______b. In a purely capacitive circuit, voltage leads current by a phase angle of 90°.

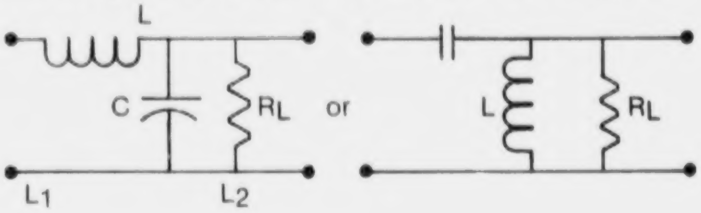
______c. In a purely inductive circuit, current leads voltage by a phase angle of 45°.

9. Discuss the relationship between time and frequency.

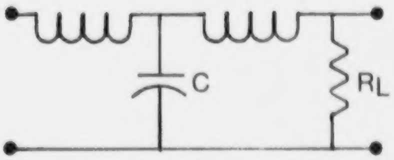
TEST

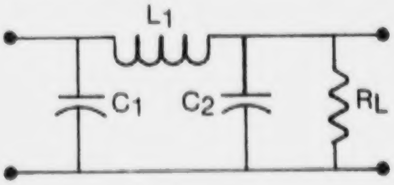
10. Identify common types of filters by writing the correct answer in the blank below each filter.

L-filter
T-filter
π-filter



a. ______________________________





b. ______________________________ c. ______________________________

11. Complete the following list of statements concerning configurations of filters by inserting the word which completes each statement.

a. High-pass

1) Coupling capacitance in ____________ with the load

2) Choke capacitance in ____________ with the load

b. Low-pass

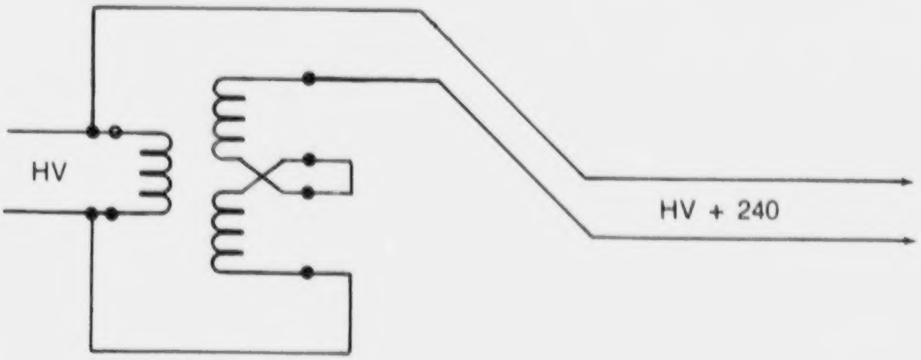
1) Choke inductance in ____________ with the load

2) Bypass capacitance in ____________ with the load

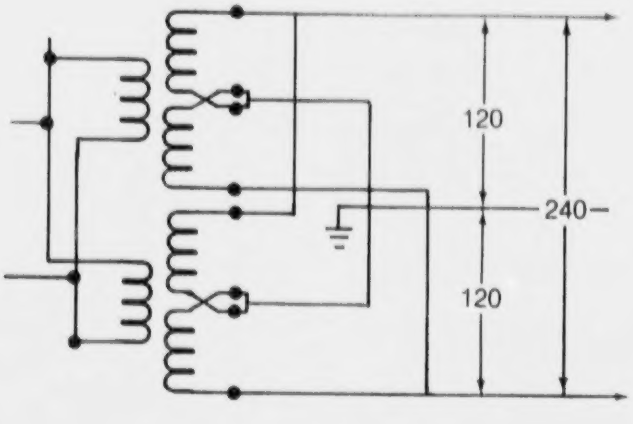
TEST

12. Identify types of single-phase transformer connections. Write the correct answer in the blank below each connection.

240 volts, two-wire	120/240 volts, three-wire with additional power capacity of two transformers
120/240 volts, three-wire	
120 volts, two-wire	208 volts, two-wire from 240 volt through autotransformer
High voltage, boosted by 240 volts	

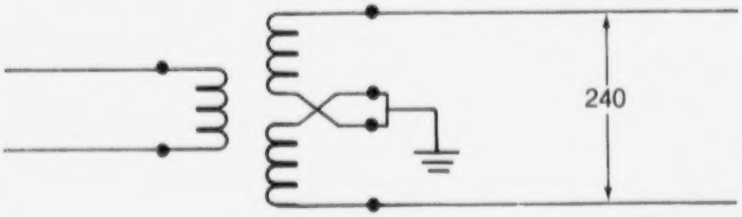


a. ______________________________

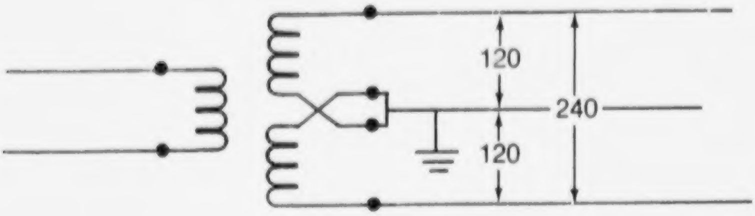


b. ______________________________

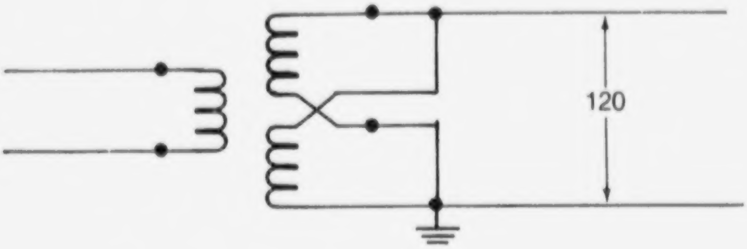
TEST



c. ____

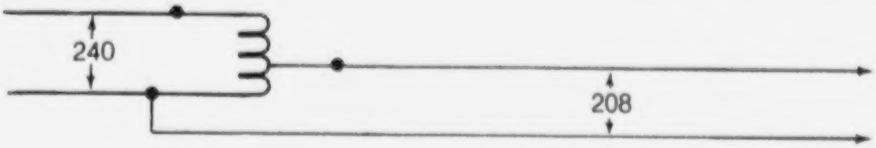


d. ____



e. ____

TEST



f. ____

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.

15. Demonstrate the ability to:

    a. Measure alternating current voltages using a multimeter. (Job Sheet #1)

    b. Measure alternating current using a multimeter. (Job Sheet #2)

    c. Determine the configuration of a multiple-winding transformer. (Job Sheet #3)

INTRODUCTION TO AC
UNIT IV

ANSWERS TO TEST

1. a. 11
   b. 7
   c. 8
   d. 2
   e. 1
   f. 5
   g. 3
   h. 9
   i. 4
   j. 6
   k. 10
   l. 12
   m. 14
   n. 15
   o. 13
   p. 21
   q. 19
   r. 16
   s. 17
   t. 29
   u. 18
   v. 25
   w. 28
   x. 23
   y. 27
   z. 24
   aa. 26
   bb. 22
   cc. 20

2. a, b, c

3. a

4. a. 6
   b. 10
   c. 1
   d. 12
   e. 9
   f. 2
   g. 8
   h. 11
   i. 5
   j. 3
   k. 4
   l. 7

5. a. 1.8 VA
   b. 623.52 VA

6. a. 4
   b. 1
   c. 2
   d. 3

7. a. 70.7 V
   b. 94.3V Pk-Pk
   c. 106.05 V
   d. 14.14 Zero-to-Peak

8. None are true

9. T = 1/Frequency = 1/f
   f = 1/Time = 1/s
   $T = (\theta/360 \times 1/f)$

10. a. π-filter
    b. L-filter
    c. T-filter

11. a. 1) Series
       2) Parallel
    b. 1) Series
       2) Parallel

ANSWERS TO TEST

12. a. High voltage, boosted by 240 volts
    b. 120/240 volts, three-wire with additional power capacity of two transformers
    c. 240 volts, two-wire
    d. 120 volts, two-wire
    e. 208 volts, two-wire from 240 volt through autotransformer
    f. 120/240 volts, three-wire

13. Performance skills evaluated to the satisfaction of the instructor

CIRCUIT COMPONENTS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to troubleshoot circuit components. Competencies will be demonstrated by correctly performing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to circuit components with their correct definitions.
2. Select equipment used in measuring quality components.
3. Complete a list of statements related to sensory factors in troubleshooting circuit components.
4. Demonstrate the ability to:
    a. Test and accept/reject, replace cells. (Job Sheet #1)
    b. Test and accept/reject, replace lamps. (Job Sheet #2)
    c. Test and accept/reject, replace switches. (Job Sheet #3)
    d. Test and accept/reject, replace resistors. (Job Sheet #4)
    e. Test and accept/reject, replace fuses and circuit breakers. (Job Sheet #5)
    f. Test and accept/reject, replace capacitors. (Job Sheet #6)
    g. Test and accept/reject, replace coils. (Job Sheet #7)

OBJECTIVE SHEET

h. Test and accept/reject, replace transformers. (Job Sheet #8)

i. Analyze the effects of temperature on a thermistor. (Job Sheet #9)

j. Test and accept/reject, repair cables and wires. (Job Sheet #10)

k. Test and accept/reject, replace relays. (Job Sheet #11)

l. Test and accept/reject, replace solenoids. (Job Sheet #12)

CIRCUIT COMPONENTS
UNIT V

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information sheet.

E. Discuss information sheet.

F. Provide students with job sheets.

G. Discuss and demonstrate the procedures outlined in the job sheets.

H. Integrate the following activities throughout the teaching of this unit:

   1. Connect circuit to provide enough current to burn out resistor to demonstrate the odor that it emits.

   2. Connect circuit to overdrive a transformer to demonstrate the sound of a transformer.

   3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

I. Give test.

J. Evaluate test.

K. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Job sheets

   1. Job Sheet #1 — Test and Accept/Reject, Replace Cells

   2. Job Sheet #2 — Test and Accept/Reject, Replace Lamps

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

3. Job Sheet #3 — Test and Accept/Reject, Replace Switches
4. Job Sheet #5 — Test and Accept/Reject, Replace Resistors
5. Job Sheet #4 — Test and Accpet/Reject, Replace Fuses and Circuit Breakers
6. Job Sheet #6 — Test and Accept/Reject, Replace Capacitors
7. Job Sheet #7 — Test and Accept/Reject, Replace Coils
8. Job Sheet #8 — Test and Accept/Reject, Replace Transformers
9. Job Sheet #9 — Analyze the Effects of Temperature on a Thermistor
10. Job Sheet #10 — Test and Accept/Reject, Repair Cables and Wires
11. Job Sheet #11 — Test and Accept/Reject, Replace Relays
12. Job Sheet #12 — Test and Accept/Reject, Replace Solenoids

E. Test

F. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

(NOTE: The following is a list of references used in completing this unit.)

A. Grob, Bernard. *Basic Electronics.* New York: McGraw-Hill Book Co.

B. Hubert, Charles. *Preventive Maintenance of Electrical Equipment.* New York: McGraw-Hill Book Co.

C. Mileaf, Harry. *Electricity One-Seven.* Hasbouck Heights, NJ: Hayden Book Company, Inc.

D. *New Mexico Vocational Industrial Safety Guide.* Santa Fe, NM: New Mexico State Department of Education.

E. Siebert, Leo N. *Introduction to Industrial Electricity-Electronics.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1981.

CIRCUIT COMPONENTS
UNIT V

INFORMATION SHEET

I. **Terms and definitions**

A. Alkaline cell — Can provide up to seven times the service of a carbon-zinc cell; output voltage is 1.5 volts; can be either primary or secondary cell

B. Battery — A group of cells connected on a series or parallel circuit

C. Carbon-zinc dry cell — Most common type of dry cell; nominal output voltage is 1.5 volts

(NOTE: Common sizes are D, C, AA, and AAA.)

D. Continuity — A condition which results in a complete path for current to flow

(NOTE: A continuity test will have a reading of zero ohms.)

E. Cycling — The process by which a battery is discharged and recharged

F. Discharge — To remove electrical energy from a charged body (capacitor or battery)

G. Dry cell — A nonrechargeable source of electrical energy produced by chemical action

H. Electrolyte — A substance which, in solution, is dissociated into ions and is capable of conducting an electrical current

I. Fusible resistor — A resistor for protecting a circuit against an overload

J. Lead-acid wet cell — Most commonly used for automobile battery; nominal output voltage is 2.1 volts; can be constructed in combinations of three (6 volt) or six cells (12 volt) batteries; lead-acid is a secondary cell and can be recharged

K. Lithium cell — Has high output voltage, long shelf life, low weight, and small volume; output voltage is either 2.9v or 3.7v, depending on the electrolyte; shelf life is ten years or more.

(CAUTION: Lithium is a very active chemical, and can have an explosive reaction that may occur without warning during use or storage.)

INFORMATION SHEET

L. Magnetic switch — A solenoid which performs a simple function, such as opening or closing a switch

M. Open (open circuit) — A condition that occurs when a circuit is broken (broken wire or open switch) that interrupts current flow

N. Primary cell — Battery that can not be recharged

O. Relay — An electrical switch which opens and closes a circuit automatically

P. Secondary cell — Battery that can be recharged

(NOTE: This is also called a storage cell.)

Q. Shelf life — Length of time a component can be stored before its operating characteristics start to degrade

(NOTE: The shelf life of dry cells can be extended by storing at a temperature between 40-50°F.)

R. Short (short circuit) — A condition that occurs when a circuit comes into contact with another part of the same circuit, causing a change in either circuit resistance or current

S. Solenoid — An electromagnet consisting of a coil with a moveable core; as current flows through the coil, the core moves, performing a mechanical action.

T. Switch — A mechanical or electrical device which breaks or completes a path for electrical current or routes it over a different path.

U. Thermistor — A temperature-compensating resistor where the resistance varies with the temperature

II. Equipment used in measuring circuit components

A. Ohmmeter — Used to measure resistance or test for continuity

B. Voltmeter — Used to measure voltage

C. Ammeter — Used to measure current flow

D. Continuity light — Used to check for a completed circuit

INFORMATION SHEET

III. Sensory factors in troubleshooting circuit components

A. Look for smoke, and discolored, swollen, or burnt components.

B. Check for hot components.

(NOTE: Some components operate warm. If a component is too hot to touch, it may be defective.)

(CAUTION: Some electronic components may generate a great deal of heat before burning out. This can cause serious burns to your hands.)

C. Check component for the smell of burnt wax or plastic. This indicates it has overheated.

(NOTE: The equipment may still operate temporarily before total failure. If so, locate any smoking components which may indicate a section to start troubleshooting.)

D. Listen for a hissing or sizzling sound. This may either be a resistor burning out or a capacitor shorting out. A high pitch whine is usually an inductor or transformer becoming defective.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #1 — TEST AND ACCEPT/REJECT, REPLACE CELLS

A. Equipment and materials needed

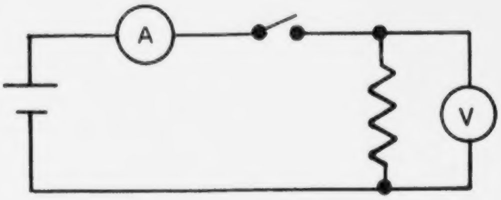
1. Hydrometer
2. Multimeter
3. 9-volt battery (carbon-zinc or alkaline cell)
4. 1K ohm resistor
5. 12-volt car battery (lead-acid wet cell)
6. SPST switch

B. Loaded voltage test procedure

1. Using the 9 volt battery and the voltmeter, measure and record the unloaded voltage.

   Battery voltage unloaded = ____________________

2. Connect the circuit below.



3. With the switch closed, measure and record the loaded voltage and the circuit current.

   Battery voltage loaded = ____________________

   Battery current loaded = ____________________

4. Calculate the internal resistance of the battery.

$$R_i = \frac{V(\text{unloaded}) - V(\text{loaded})}{I(\text{loaded})} = \_\_\_\_\_\_\_\_$$

JOB SHEET #1

5. Using the following chart(s), determine whether the battery is

Good________ or Bad________

CELL CHARACTERISTICS

Cell Size	Internal Resistance	Current Drain(ma)	Life Hours
N	0.69 Ohm's	1.5	275
		7.5	52
		15	24
AA	0.29 Ohm's	3	350
		15	40
		30	15
AAA	0.44 Ohm's	2	290
		10	45
		20	17
C	0.47 Ohm's	5	420
		25	100
		50	40
D	0.27 Ohm's	10	500
		50	105
		100	45

TYPICAL CELL VOLTAGE RATINGS

	Voltage Ratings		
Type of Cell	No Load	Loaded	Discharged
Copper-zinc sulfuric acid, primary wet cell	1.08	1.008	0.8
Carbon-zinc-chromic acid, primary wet cell	2.0	1.9	1.7
Carbon-zinc-ammonium chloride, primary dry cell	1.5	1.4	1.2
Mercury-zinc-potassium hydroxide, primary dry cell	1.34	1.31-1.24	1.0
Lead-acid storage cell	2.1	2.0	1.75
Nickel-iron, alkaline storage cell	1.37	1.3	1.0
Nickel-cadmium, alkaline storage cell	1.3	1.2	1.0
Silver-zinc, alkaline storage cell	1.95	1.86	1.6

JOB SHEET #1

C. Specific gravity test procedure

1. Obtain car battery from instructor.
2. Remove the lid from the cell to be tested.

   (CAUTION: Be extremely careful not to spill any fluid on your clothes or skin. Do not blow into the cell as fluid may splash back into your eyes.)

3. Compress bulb syringe on hydrometer and insert into cell.
4. Release bulb and allow to fill with fluid.
5. Remove the hydrometer and check the level on the graduated scale.
6. Check the scale reading against the table below and determine the amount of charge. ______________

SPECIFIC GRAVITIES

From	To	Charge
1.260	1.280	100%
1.230	1.250	75%
1.200	1.220	50%
1.170	1.190	25%
1.140	1.160	Very little useful capacity
1.110	1.130	Discharged

7. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

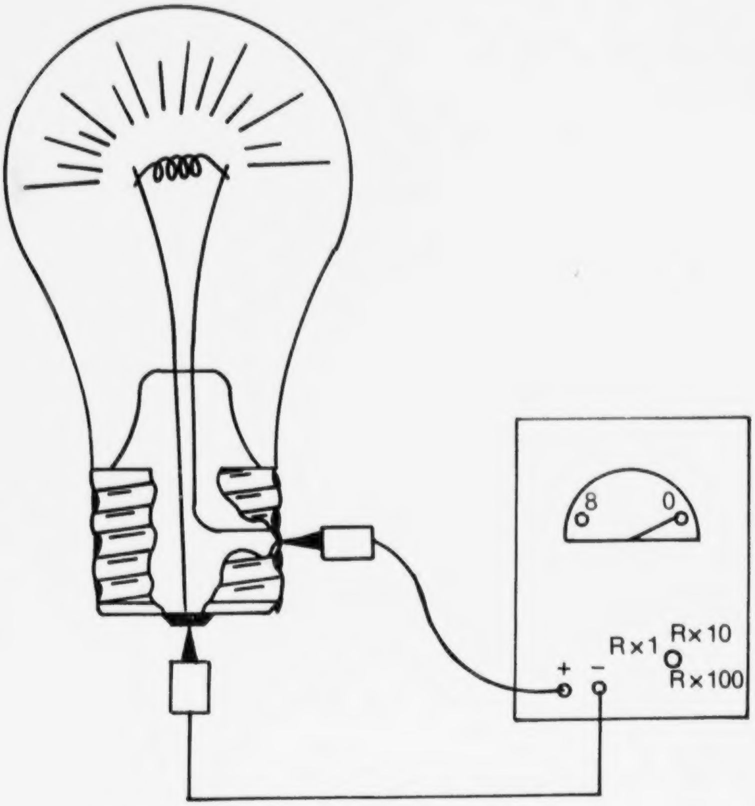
JOB SHEET #2 — TEST AND ACCEPT/REJECT, REPLACE LAMPS

A. Equipment and materials needed

1. Ohmmeter
2. Continuity light
3. Assorted good and bad lamps

B. Procedure

1. Connect the ohmmeter as shown below.



JOB SHEET #2

2. Accept if the ohmmeter indication is near zero.
3. Reject if the ohmmeter indication is near infinite.
4. Connect the continuity light in place of the ohmmeter.
5. Accept if continuity exists.
6. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

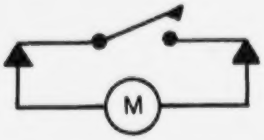
JOB SHEET #3 — TEST AND ACCEPT/REJECT, REPLACE SWITCHES

A. Equipment and materials needed

1. Ohmmeter
2. Continuity light
3. SPST wall switch
4. Push button switch
5. Toggle switch
6. Micro switch
7. Rotary switch multiposition
8. Any switch mounted in a non-powered circuit

B. Procedure

1. Connect the ohmmeter to the SPST switch as shown below.



(NOTE: For switches with multipositions, test each position for proper operation.)

2. Place switch in the "off" or "open" position.
3. Check for an ohmmeter reading of infinite resistance.
4. Place switch in the "on" or "closed" position.
5. Check for an ohmmeter reading of zero resistance.
6. Accept if all of the above conditions are met; otherwise, reject or replace the switch.
7. Repeat Steps 1 through 6 for each switch.
8. Use the continuity light in place of the ohmmeter and repeat Steps 1 through 7, checking for continuity in the "on" or "closed" position.
9. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #4 — TEST AND ACCEPT/REJECT, REPLACE RESISTORS

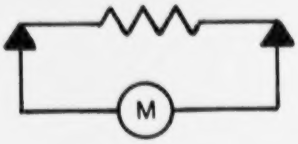
A. Equipment and materials needed

1. Multimeter
2. Assortment of resistors
3. Potentiometer
4. Rheostat

B. Procedure

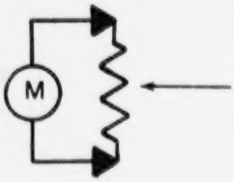
1. Determine the value of each resistor given and enter this value in Table 1.
2. Using the tolerance of each resistor, determine the maximum and minimum value for each resistor. Record this value in Table 1.
3. Connect the ohmmeter as shown in Figure 1.

FIGURE 1



4. Read the measured value of each resistor and record in Table 1.
5. Indicate whether the resistor is within tolerance by recording an (A) accept or (R) reject in Table 1.
6. Read the value of the potentiometer from the case and record the value in Table 1.
7. Connect the potentiometer as shown in Figure 2.

FIGURE 2

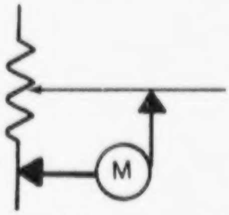


8. Measure the total resistance of the potentiometer and record in Table 1.

JOB SHEET #4

9. Connect the potentiometer as shown in Figure 3.

FIGURE 3



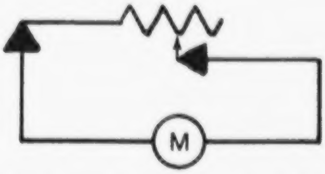
10. Turn the shaft to vary the resistance, and observe if there is a smooth increase and decrease in resistance as the shaft is turned.

11. If resistance movement is not smooth (ohmmeter reading jumps in resistance as shaft is turned), indicate (R) reject in Table 1.

12. Read the value of the rheostat from the case and record the value in Table 1.

13. Connect the rheostat as shown in Figure 4.

FIGURE 4



14. Turn the shaft to vary the resistance, and observe if there is a smooth increase and decrease in resistance as the shaft is turned.

15. If resistance movement is not smooth (ohmmeter reading jumps in resistance as shaft is turned), indicate (R) reject in Table 1.

TABLE 1

	Color Code Value	Minimum Resistance	Maximum Resistance	Measured Resistance	Accept/ Reject
Resistor 1					
Resistor 2					
Resistor 3					
Resistor 4					
Resistor 5					
Resistor 6					
Resistor 7					
Resistor 8					
Resistor 9					
Resistor 10					
Potentiometer					
Rheostat					

16. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #5 — TEST AND ACCEPT/REJECT, REPLACE FUSES AND CIRCUIT BREAKERS

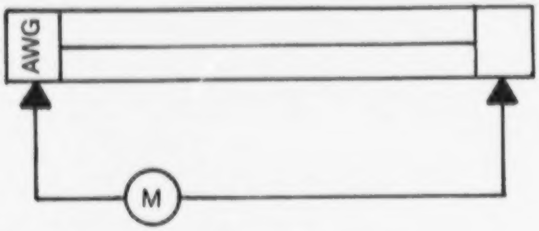
A. Equipment and materials needed

1. Multimeter
2. Continuity light
3. Assorted good and bad fuses
4. Circuit breaker

B. Procedure

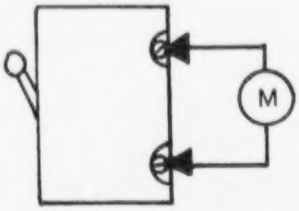
1. Connect the ohmmeter as shown in Figure 1.

FIGURE 1



2. Accept if the ohmmeter indication is near zero.
3. Reject if the ohmmeter indication is near infinite.
4. Connect the continuity light in place of the ohmmeter.
5. Accept if continuity exists.
6. Connect the ohmmeter to the circuit breaker as shown in Figure 2.

FIGURE 2



JOB SHEET #5

7. Place the circuit breaker in the "off" or "open" position.

8. Check for an ohmmeter reading of infinite resistance.

9. Place circuit breaker in the "on" or "closed" position.

10. Check for an ohmmeter reading of zero resistance.

11. Accept if all of the above conditions are met; otherwise, reject or replace the circuit breaker.

12. Use the continuity light in place of the ohmmeter and repeat Steps 7 through 9 checking for continuity in the "on" or "closed" position.

    (NOTE: A circuit breaker which indicates it is good by this test should also be checked under operating conditions.)

13. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #6 — TEST AND ACCEPT/REJECT, REPLACE CAPACITORS

A. Equipment and materials needed

1. Multimeter
2. Three known, good capacitors (large, medium, small, e.g. less than $0.1\mu f$)
3. Shorted capacitor
4. Open capacitor
5. Leaky capacitor

B. Procedure

1. Place the ohmmeter leads across the large (good) capacitor.
2. Note the swing of the needle across the scale to zero and its return to infinity as the capacitor is charged by the ohmmeter battery.
3. Repeat Steps 1 and 2 with the medium and with the small (good) capacitors.

   (NOTE: Notice the smaller deflection of the needle during charge.)
4. Place the ohmmeter leads across the open capacitor.

   (NOTE: Notice the lack of any deflection of the ohmmeter needle, indicating no current path.)
5. Place the ohmmeter leads across the shorted capacitor.

   (NOTE: Notice that the needle indicates zero ohms resistance (no return toward infinity and thus no charging of the capacitor plates.)
6. Place the ohmmeter leads across the leaky capacitor.

   (NOTE: Notice the return of the needle to some specific resistance indication rather than a return to infinity.)
7. Place the ohmmeter leads across the medium sized (good) capacitor and permit the indication to return to infinity.
8. Reverse the ohmmeter leads and observe the difference in initial ohmmeter needle indication.

JOB SHEET #6

9. Repeat Steps 7 and 8 using the small (good) capacitor.
10. Discuss your findings with your instructor.
11. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #7 — TEST AND ACCEPT/REJECT, REPLACE COILS

A. Equipment and materials needed

1. Inductance meter
2. Inductors — Type determined by your instructor
3. Instruction booklet

B. Procedure

1. Use the instruction booklet to review the operating instructions for the inductance tester.
2. Follow the operating instructions for use of the inductance tester.
3. Measure the inductance of the inductor.
4. Record the value below.

   L = ____________________

5. Make a ringing test on the inductor.
6. Does the inductor meet specifications? ____________________
7. Repeat Steps 3 through 6 for each inductor being tested.
8. Record values below.

   Inductance ______________ Ringing Test ______________

   Inductance ______________ Ringing Test ______________

   Inductance ______________ Ringing Test ______________

9. Compare the inductance reading with the values of the inductors.

   (NOTE: Show your results to the instructor.)

10. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #8 — TEST AND ACCEPT/REJECT, REPLACE TRANSFORMERS

A. Equipment and materials needed

1. Miltimeter
2. Multilead transformer
3. Six inch strip of masking tape
4. Pen or pencil

B. Procedure

1. Determine the primary side of the transformer by color code if possible.

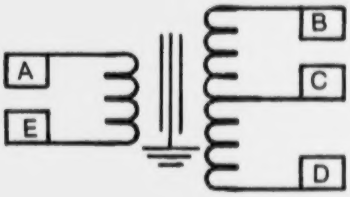
   (NOTE: Color code for power transformers is as follows:

   Primary without center tap — Both black
   Primary with center tap — Common = Black
   Tap = Black and yellow
   End = Black and red)

2. If color coding cannot be read, then tag each lead of the transformers with a small piece of tape and label them A — Z.

3. Connect the common lead of the ohmmeter to lead A, and the red lead to B. If the ohmmeter indicates low resistance, draw the symbol for an inductor with one end as "A" and the other as "B", or whichever lead is being tested.

   Example:



4. Repeat Step #3 for all unidentified leads.

5. Once all leads have been identified, check for any shorts to the core by connecting the common ohmmeter lead to the core and the red ohmmeter lead to each of the other transformer leads.

   (NOTE: If leads cannot be identified, this indicates an open position.)

6. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

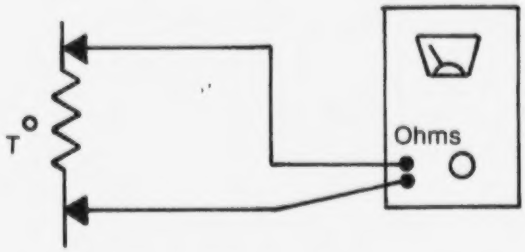
JOB SHEET #9 — ANALYZE THE EFFECTS OF TEMPERATURE ON A THERMISTOR

A. Equipment and materials needed

1. Multimeter
2. Thermistor (A919a)
3. Heat source

B. Procedure

1. Connect the thermistor as shown below.



2. Set the multimeter to read ohms at a range that will show an indication at the highest value of the thermistor.

3. Heat the thermistor and observe the ohmmeter movement.

4. If the ohmmeter does not move as heat is applied or the movement is not smooth, replace the thermistor.

   (NOTE: Movement of the ohmmeter is not a reliable test of a thermistor.)

5. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #10 — TEST AND ACCEPT/REJECT, REPAIR CABLES AND WIRES

A. Equipment and materials needed

1. Continuity light
2. Unshielded cable with an open conductor
3. Unshielded cable with a short
4. Soldering iron and solder
5. Wire strippers

B. Procedure (cable configuration known)

1. Start at pin one on the cable connector and, using the continuity light, check for any shorts to other pins.
2. If any connector pins are shorted, proceed to procedure D.
3. Repeat Step 1 until all pins have been checked against each other.
4. Check for continuity from pin one on one end of the cable to the corresponding pin on the other end of the cable.
5. If no continuity is present at one of the points, then proceed to procedure E.
6. Repeat Steps 3 and 4 for each pin of the the cable.

C. Procedure (cable configuration unknown)

1. On a piece of paper, number from 1 to the number of pins on the connector (1, 2, 3, . . ., N).
2. Start at pin one on the cable connector and, using the continuity light, check for any shorts to other pins.
3. If any connector pins are shorted, proceed to procedure D.
4. Repeat Step 1 until all pins have been checked against each other.
5. Check from pin 1 on end "A" of the cable to pin 1 on end "B" of the cable for continuity. If continuity is present, draw a line across from pin 1 and write the corresponding pin number from end "B" next to the line.
6. If no continuity is present, move to the next pin on end "B" and repeat Step 5 until all pins on end "B" have been checked.

JOB SHEET #10

7. Repeat Steps 5 and 6 for each pin on end "A" of the cable.
8. If a pair of pins indicate no continuity, then proceed to procedure E.

D. Procedure (short repair)

1. Visually inspect both cable connectors for solder bridges. If any exist, remove them with the soldering iron.
2. If no solder bridges are present, disconnect 1 of the cable leads from the connector and retest for continuity. If continuity is still present between the two pins on the connector, replace the connector.
3. Separate the two conductors from the rest of the cable.
4. Pull the two conductors apart until the short is located.
5. Insulate the shorted area with either electrical tape or shrink tubing.
6. Reinstall loose conductor to cable connector.
7. Retest cable to ensure all shorts have been found and repaired.

E. Procedure (open repair)

1. Visually inspect the cable connector for any broken connections between the connector pin and the conductor.
2. If the open is caused by a broken connection to the cable connector, resolder the connection then retest.
3. If the connection to the pins of both cable connectors is made and the open still exists, then connect the common test lead to the pin.
4. Using a straight pin, probe the connector from the other end until continuity is found.

   (NOTE: Use half the distance between test points to determine the next test point.)
5. Once the open is found in the conductor, strip the insulation back and tin the wire.
6. Place a piece of shrink tubing on one of the conductors to be connected.
7. Twist and solder the two ends together.
8. Slide the shrink tubing over the connection and apply heat.
9. Retest the cable to ensure all repairs have been made.
10. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #11 — TEST AND ACCEPT/REJECT, REPLACE RELAYS

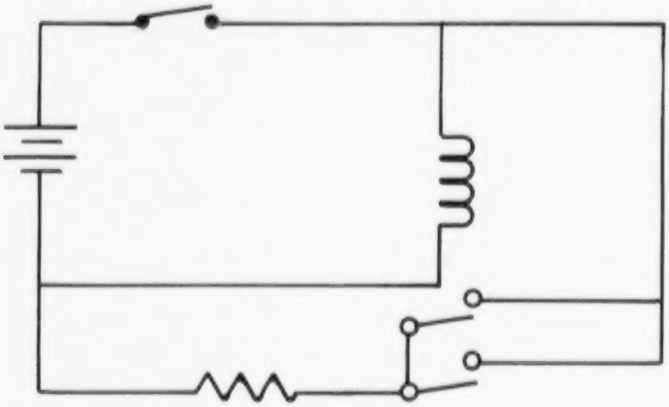
A. Equipment and materials needed

1. Multimeter
2. Relay — DPDT
3. SPST switch
4. Power supply
5. Resistor — 10K ohm
6. Test leads

B. Procedure

1. Construct circuit shown below.

   (NOTE: Be sure power supply is turned off and voltage is adjusted to zero.)



2. Turn on power supply.
3. Adjust power supply voltage to value specified by instructor.

JOB SHEET #11

4. Measure voltages across the relay terminals while operating the relay until the terminals can be identified and the contacts are determined to be satisfactory or defective.

   (NOTE: If assistance is needed, see your instructor.)

5. Explain how energizing the relay affected the voltage measurements of the relay contacts.

   ____

   ____

   ____

   ____

   (NOTE: Check your results with the instructor.)

6. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

JOB SHEET #12 — TEST AND ACCEPT/REJECT, REPLACE SOLENOIDS

A. Equipment and materials needed

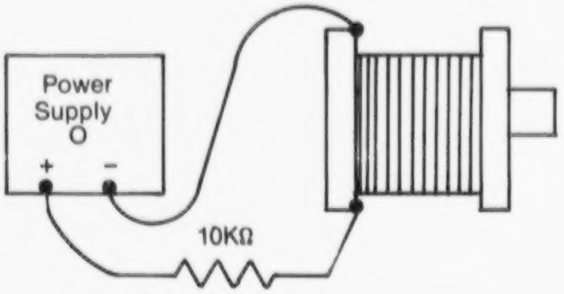
1. Multimeter
2. Solenoid
3. Power supply
4. 10K ohm resistor
5. Test leads

B. Procedure

1. Set the multimeter to the ohms scale and measure the resistance across the solenoid coil.

   (NOTE: Coil resistance should be very low.)

2. Set the multimeter to the volts scale and measure the power supply voltage. Adjust power supply to zero volts. Turn off power supply.
3. Connect the circuit shown below.



4. Turn on power supply.
5. Adjust voltage and observe movement of solenoid shaft.
6. If solenoid shaft does not move freely, replace solenoid.
7. Return equipment and materials to their proper storage area.

CIRCUIT COMPONENTS
UNIT V

NAME ____________________

TEST

1. Match the terms on the right with their correct definitions.

(NOTE: Answers to questions a.-l. appear on this page.)

_____a. The process by which a battery is discharged and recharged

_____b. To remove electrical energy from a charged body (capacitor or battery)

_____c. A nonrechargeable source of electrical energy produced by chemical action

_____d. A substance which, in solution, is dissociated into ions and is capable of conducting an electrical current

_____e. A resistor for protecting a circuit against an overload

_____f. A solenoid which performs a simple function, such as opening or closing a switch

_____g. A condition that occurs when a circuit is broken (broken wire or open switch) that interrupts current flow

_____h. An electrical switch which opens and closes a circuit automatically

_____i. A condition that occurs when a circuit comes into contact with another part of the same circuit, causing a change in either circuit resistance or current

_____j. An electromagnet consisting of a coil with a moveable core; as current flows through the coil, the core moves, performing a mechanical action

_____k. A mechanical or electrical device which breaks or completes a path for electrical current or routes it over a different path

_____l. A temperature-compensating resistor where the resistance varies with the temperature

1. Thermistor
2. Fusible resistor
3. Discharge
4. Solenoid
5. Open (open circuit)
6. Electrolyte
7. Relay
8. Dry cell
9. Switch
10. Cycling
11. Short (short circuit)
12. Magnetic switch

TEST

(NOTE: Answer to questions m.-u. appear on this page.)

_____m. Battery that can not be recharged

_____n. Battery that can be recharged

_____o. Most common type of dry cell; nominal output voltage is 1.5 volts.

_____p. Length of time a component can be stored before its operating characteristics start to degrade

_____q. Can provide up to seven times the service of a carbon-zinc cell; output voltage is 1.5 volts; can be either primary or secondary cell.

_____r. Has high output voltage, long shelf life, low weight, and small volume; output voltage is either 2.9v or 3.7v, depending on the electrolyte; shelf life is ten years or more.

_____s. Most commonly used for automobile battery; nominal output voltage is 2.1 volts; can be constructed in combinations of three (6 volt) or six (12 volt) batteries; lead-acid is a secondary cell and can be recharged

_____t. A condition which results in a complete path for current to follow

_____u. A group of cells connected on a series or parallel circuit

13. Primary cell
14. Secondary cell
15. Continuity
16. Lithium cell
17. Shelf life
18. Lead-acid wet test
19. Battery
20. Carbon-zinc dry cell
21. Alkaline cell

2. Select from the following list equipment used in measuring circuit components by placing an "X" in the blanks next to the correct equipment.

_____a. Rheostat

_____b. Voltmeter

_____c. Continuity light

_____d. Ohmmeter

TEST

______e. Potentiometer

______f. Ammeter

______g. Hydrometer

3. Complete the following list of statements related to sensory factors in troubleshooting circuit components by inserting the word(s) which best complete(s) each statement.

   a. Look for ____________, and discolored, swollen, or burnt components.

   b. Check for ____________ components.

   c. Check component for the smell of burnt wax or plastic. This indicates it has ____________.

   d. Listen for a ____________ or ____________ sound. This may either be a resistor burning out or a capacitor shorting out.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

4. Demonstrate the ability to:

   a. Test and accept/reject, replace cells. (Job Sheet #1)

   b. Test and accept/reject, replace lamps. (Job Sheet #2)

   c. Test and accept/reject, replace switches. (Job Sheet #3)

   d. Test and accept/reject, replace resistors. (Job Sheet #4)

   e. Test and accept/reject, replace fuses and circuit breakers. (Job Sheet #5)

   f. Test and accept/reject, replace capacitors. (Job Sheet #6)

   g. Test and accept/reject, replace coils. (Job Sheet #7)

   h. Test and accept/reject, replace transformers. (Job Sheet #8)

   i. Analyze the effects of the temperature on a thermistor. (Job Sheet #9)

   j. Test and accept/reject, repair cables and wires. (Job Sheet #10)

   k. Test and accept/reject, replace relays. (Job Sheet #11)

   l. Test and accept/reject, replace solenoids. (Job Sheet #12)

CIRCUIT COMPONENTS
UNIT V

ANSWERS TO TEST

1. a. 10
   b. 3
   c. 8
   d. 6
   e. 2
   f. 12
   g. 5
   h. 7
   i. 11
   j. 4
   k. 9
   l. 1
   m. 13
   n. 14
   o. 20
   p. 17
   q. 21
   r. 16
   s. 18
   t. 15
   u. 19

2. b, c, d, f

3. a. Smoke
   b. Hot
   c. Overheated
   d. Hissing, sizzling

4. Performance skills evaluated to the satisfaction of the instructor.

BASIC POWER SUPPLIES
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to construct basic power supplies, test basic power supplies, and use an ohmmeter to determine the anode and cathode of diodes. Competencies will be demonstrated by correctly performing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to basic power supplies with their correct definitions.
2. Sketch a P-N junction and label the P material, the N material, the depletion region, and the barrier potential showing voltage ranges for the silicon and germanium diodes.
3. Describe biasing effects on the P-N junction.
4. Draw and label the schematic symbol for a diode.
5. List three reasons for diode failure.
6. Match output waveforms with their correct circuits.
7. Match power supply components with their correct applications.
8. Match basic power supply functions with their correct descriptions.
9. Identify voltage regulator circuit schematics.
10. Complete a list of statements concerning troubleshooting the basic power supply.

OBJECTIVE SHEET

11. Demonstrate the ability to:
    - a. Use an ohmmeter to determine the anode and cathode of diodes. (Job Sheet #1)
    - b. Check transistors for proper operation. (Job sheet #2)
    - c. Construct and test a half-wave rectifier circuit. (Job Sheet #3)
    - d. Construct and test a full-wave bridge rectifier circuit. (Job Sheet #4)
    - e. Construct and test a capacitor filter circuit. (Job Sheet #5)
    - f. Construct and test a Pi-section filter circuit. (Job Sheet #6)

BASIC POWER SUPPLIES
UNIT VI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Show various power supply configurations of rectifiers, filters, etc. to students.
   2. Have students identify types of power supplies in several different pieces of equipment.
   3. Have students troubleshoot defective power supplies.
   4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Suggested activities

C. Information sheet

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

D. Transparency masters

    1. TM 1 — Biasing Effects on the P-N Junction
    2. TM 2 — Half-Wave Rectifier Circuits
    3. TM 3 — Full-Wave Rectifier
    4. TM 4 — Full-Wave Bridge Rectifier
    5. TM 5 — Silicon Controlled Rectifier
    6. TM 6 — Triac Controlled Power Supply
    7. TM 7 — Simple Regulated Power Supply
    8. TM 8 — Regulated Power Supply Block Diagram

E. Job sheets

    1. Job Sheet #1 — Use an Ohmmeter to Determine the Anode and Cathode of Diodes
    2. Job Sheet #2 — Check Transistors for Proper Operation
    3. Job Sheet #3 — Construct and Test a Half-Wave Rectifier Circuit
    4. Job Sheet #4 — Construct and Test a Full-Wave Bridge Rectifier Circuit
    5. Job Sheet #5 — Construct and Test a Capacitor Filter Circuit
    6. Job Sheet #6 — Construct and Test a Pi-Section Filter Circuit

F. Test

G. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

(NOTE: The following is a list of references used in completing this unit.)

A. Grob, Bernard. *Application of Electronics.* New York: McGraw-Hill Book Company.

B. Harwick, Jim. *General Industrial Electronics.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

C. *Introduction to Power Supplies.* Barrington, IL: TPC Training Systems, Division of Technical Publishing Company, 1977.

D. Robertson, L. Paul. *Basic Electronics I (Revised Edition).* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

E. Shrader, Robert L. *Electronic Communications,* Third Edition. New York: McGraw-Hill Book Company, 1975.

BASIC POWER SUPPLIES
UNIT VI

INFORMATION SHEET

I. **Terms and definitions**

A. Bleeder resistor — Resistor connected across filter capacitors to drain charge when circuit power is turned off

(CAUTION: Large capacitors may store a charge sufficient enough to result in injury or death if contacted accidentally. Bleeder resistors reduce this hazard, but they may not always be present or may not be functional.)

(NOTE: Technicians should check or bleed large capacitors properly before working near them. Review the unit on capacitors for proper procedures to use when discharging large capacitors.)

B. Choke — Inductor used in a DC power supply to reduce ripple at the output

C. Power supply — Circuit or device that provides a specific electrical output by transforming a different electrical input or converting other forms of energy

Examples: Battery, electrical generator, AC to DC converter

(NOTE: A battery converts chemical energy to electrical energy. A generator converts mechanical energy to electrical energy. An AC to DC converter transforms AC power to DC power.)

D. Regulator — Circuit or device that serves to keep voltage or current output at a constant level

E. Ripple — Low-amplitude variation of DC power; usually results from insufficient filtering of rectified AC

F. Series regulator — Controller placed in line with the load; controls by varying resistance to the load current

Example: Q1 of Transparency 7

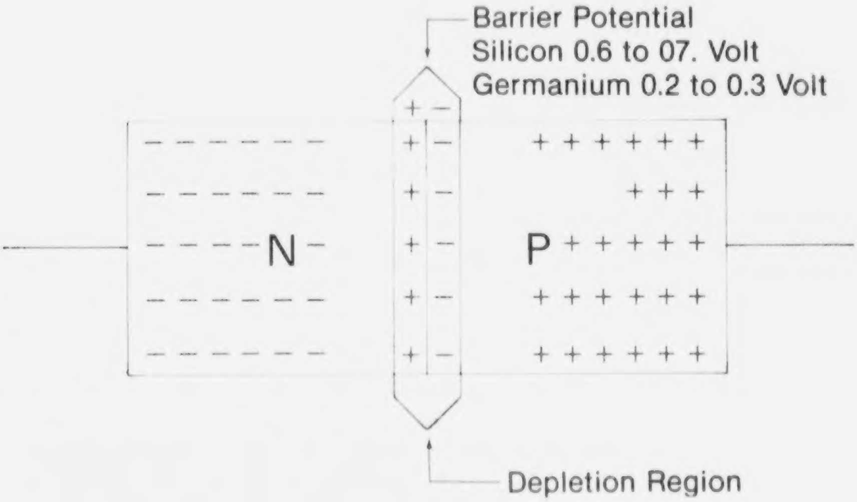
H. Shunt regulator — Controller placed in parallel to the load; bypasses excessive current and varies total current through a series resistance to control output voltage

INFORMATION SHEET

II. Depletion or barrier region of a P-N junction and the barrier potential

A. Silicon diode barrier potential = 0.6 to 0.7 volts

B. Germanium diode barrier potential = 0.2 to 0.3 volts


Barrier Potential
Silicon 0.6 to 07. Volt
Germanium 0.2 to 0.3 Volt
N
P
Depletion Region

III. Biasing effects on the P-N junction (Transparency 1)

A. Forward bias — Positive potential is connected to the P-type material allowing current to flow

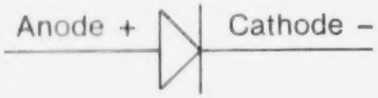
B. Reverse bias — Positive potential is connected to the N-type material restricting current flow

IV. Diode schematic symbols

A. Anode + P-section

B. Cathode − N-section

C. Symbol —


Anode +
Cathode −

(NOTE: The arrow points to the N-type material.)

INFORMATION SHEET

V. Reasons for diode failure

(NOTE: The reasons for diode failure listed here are given in the approximate order of frequency of occurrence, beginning with the most common reason.)

A. Heat

Examples: Failing to use heat sink when soldering or unsoldering leads; restricted air flow in equipment cabinets due to clogged air screens or defective cooling fans; using too large soldering iron when installing or removing diodes

(NOTE: Stud-mounted diodes are often supplied with an insulating washer to be used when it is necessary to electrically insulate them from the chassis. This washer also restricts heat transfer and should not be used unless it is necessary. Silicon grease aids in heat transfer whether the insulating washer is used or not. Silicon grease also prevents corrosion and ensures electrical contact.)

B. Shock/stress

Examples: Dropping components onto hard surfaces; cutting component leads with cutters that cause a sharp snap of the leads; jarring printed circuit boards; using excessive pressure on stud-mounted diodes; contraction and expansion due to temperature extremes, particularly where axial-lead diodes are installed with the leads directly between terminal points with no bends; flexing or bending of printed circuit boards

C. Excessive current

Examples: High-voltage spikes created by lightning; surges in the power distribution system; poor electrical connections; installation in reverse

VI. Rectifier circuits and output waveforms

A. Half-wave (Transparency 2)

B. Full-wave (Transparency 3)

C. Full-wave rectifier bridge (Transparency 4)

D. Silicon controlled rectifier (SCR) (Transparency 5)

(NOTE: SCRs may be used in full-wave bridge rectifiers where they serve the dual purpose of rectifying and regulating.)

INFORMATION SHEET

E. Triac (Transparency 6)

(NOTE: Traic may be used to regulate the AC power input to control the DC power output of a power supply. It is important to note that the power is not wasted even when a waveform is half-wave or chopped. That portion of power excluded is merely rejected as if the power switch were turned off for that instant. Thus the actual power out of a half-wave rectifier is not one-half of the power in. Except for transformer losses and diode leakage current, all of the diode circuits shown in this objective output the same power as is input. No significant power is lost; it is merely rejected. For this reason, diode, SCR, and Triac circuits are far more efficient than rheostats for controlling power.)

VII. **Power supply components and their applications** (Transparency 7)

A. Transformer

1. Used to step AC voltages up or down
2. May be used for isolation
3. May have multiple taps for varying output voltage
4. Required with center-tapped output for some types of rectifier circuits

B. Diode

1. Used for rectification of AC (solid-state device)
2. Used for reference voltage or regulation (Zener)
3. Used as a controllable rectifier and frequently as a switch (SCR)
4. Used to vary AC voltage levels by switching on and off (Triac)

C. Capacitor — Used to filter pulsating DC

D. Inductor — Used to filter pulsating DC

E. Transistor

1. Used as active control element to regulate voltage or current
2. Used as comparator of output and reference

INFORMATION SHEET

VIII. **Basic power supply functions and their descriptions** (Transparencies 7 and 8)

A. Sample — Component or elements of a power supply that measure portion of supply voltage as feedback for controlling circuitry

(NOTE: The sample is usually a voltage-divider network.)

Examples: R_2, R_3 and R_4 of Transparency 7

B. Reference — Component or elements of a power supply that maintain constant voltage for the purpose of comparison by controlling circuitry

(NOTE: The reference element is usually a Zener diode but could be an integrated circuit.)

Example: C_{R_5} of Transparency 7

C. Comparator — Component or elements of a power supply that monitor voltages to detect error and produce a correction voltage for compensating circuitry

Example: Q_3 of Transparency 7

D. Error amplifier — Circuitry or components of a power supply that boost the error-detected correction voltage to a power level sufficient to operate the compensating circuitry

Example: Q_2 of Transparency 7

E. Control circuitry — Components of a power supply that actually control the supply output

Example: Q_1 of Transparency 7

F. Filter — Component or elements of a power supply that reduce ripple and noise

Examples: C_1 of Transparency 7

G. Rectifier — Circuitry or element of a power supply that transforms AC to pulsating DC

Examples: C_{R_1}, C_{R_2}, C_{R_3}, and C_{R_4} of Transparency 7

INFORMATION SHEET

H. Transformer — Circuitry or component of a power supply that changes the voltage level

Example: T_1 of Transparency 7

(NOTE: Transformers function as modifiers for AC, while simple resistor networks can suffice for DC voltage reduction. SCRs can modify AC voltage in conjunction with filtering.)

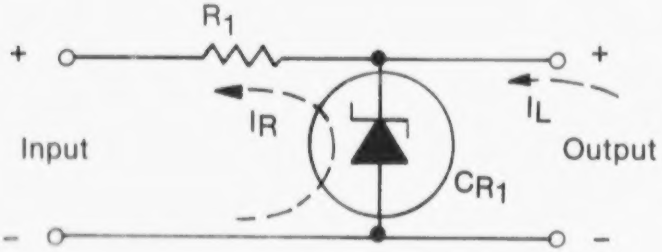
I. Adjust circuitry — Components of a power supply that allow for changing the output

Example: R_3 of Transparency 7

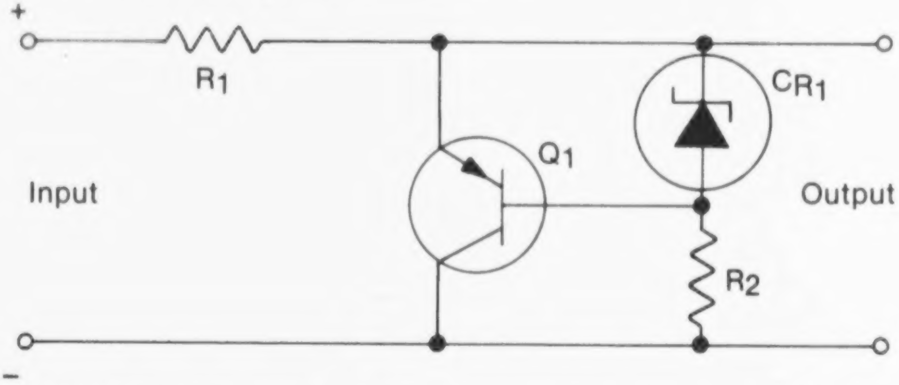
IX. Voltage regulator circuit schematics

A. Zener diode shunt regulator

(NOTE: The Zener diode operates in the reverse-bias mode.)



B. Transistor shunt regulator



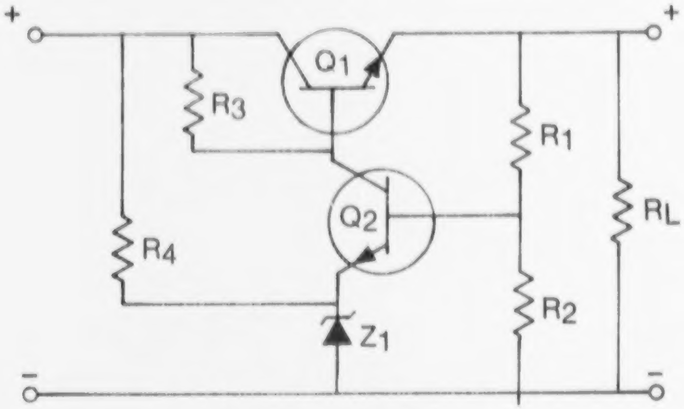
(NOTE: In this instance CR_1 is acting as a voltage reference to bias Q_1 base current.)

INFORMATION SHEET

C. Transistor series regulator

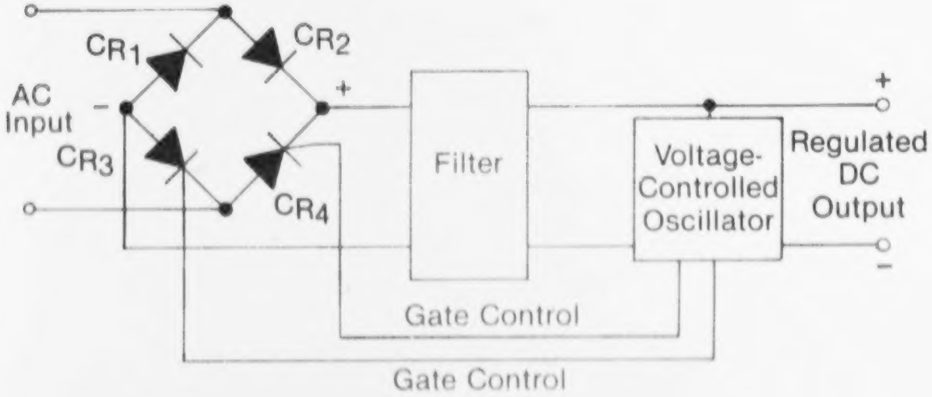
Example: Q_1 of Transparency 7

(NOTE: When the voltage output decreases, the voltage drop across R_4 decreases, so less current flows through CR_1. Thus, less voltage is applied to the base of Q_2, causing less conduction. This increases the voltage at the base of Q_1 and allows more current flow through Q_1, adjusting the output to the load.)


+
+
Q1
R3
R1
Q2
RL
R4
R2
Z1
−
−

D. Thyristor regulator

Examples: SCR and Triac


CR1
CR2
+
+
AC
Input
−
Filter
Voltage-
Controlled
Oscillator
Regulated
DC
Output
CR3
CR4
−
Gate Control
Gate Control

(NOTE: C_{R_3} and C_{R_4} are SCR diodes.)

INFORMATION SHEET

X. **Troubleshooting the basic power supply**

A. Disconnect load from power supply and check to see if problem still exists.

B. Check filtering capacitors for charging.

(NOTE: If charging is not present, disconnect one lead of the capacitor and recheck for charging. If shorted, replace the capacitor.)

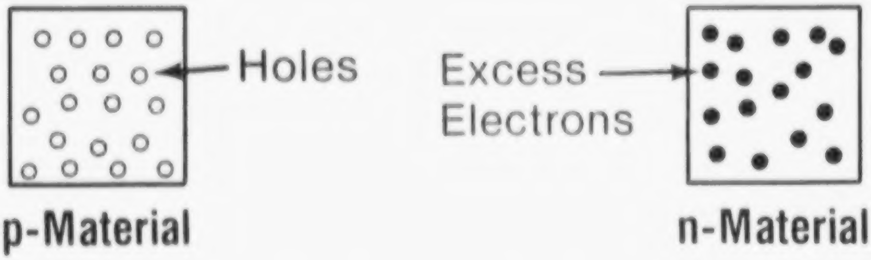
C. Check rectifier diodes for proper operation.

D. Check all resistors for proper value.

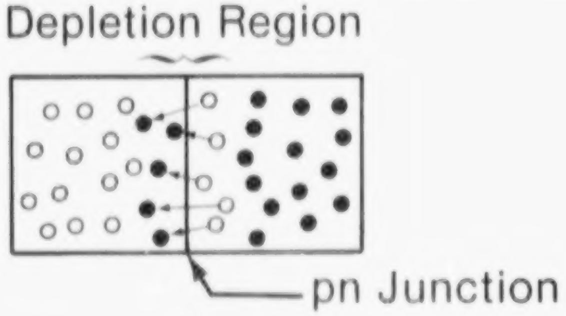
E. Check transistors for proper operation.

(NOTE: If all components check "OK" then disconnect the rectifier from the transformer and turn power on. If AC voltage is not present on the secondary, replace the transformer.)

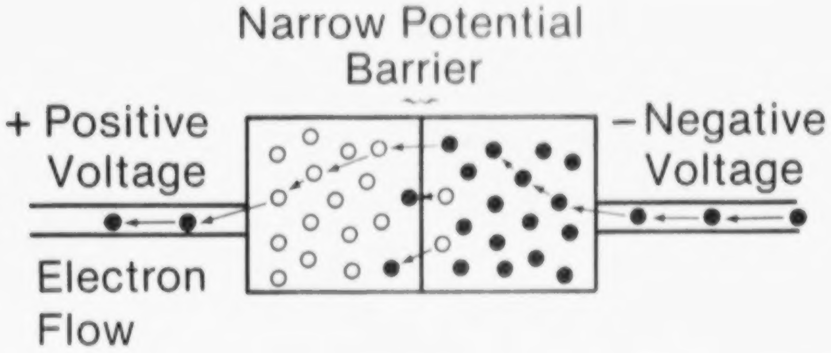
Biasing Effects on the P-N Junction


Holes
Excess Electrons
p-Material
n-Material

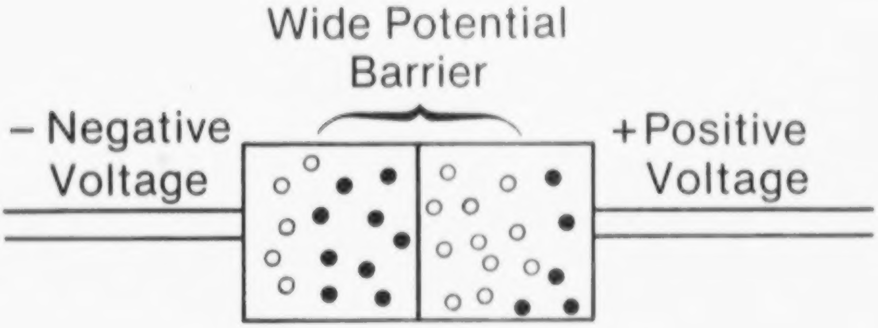
Unbiased


Depletion Region
pn Junction

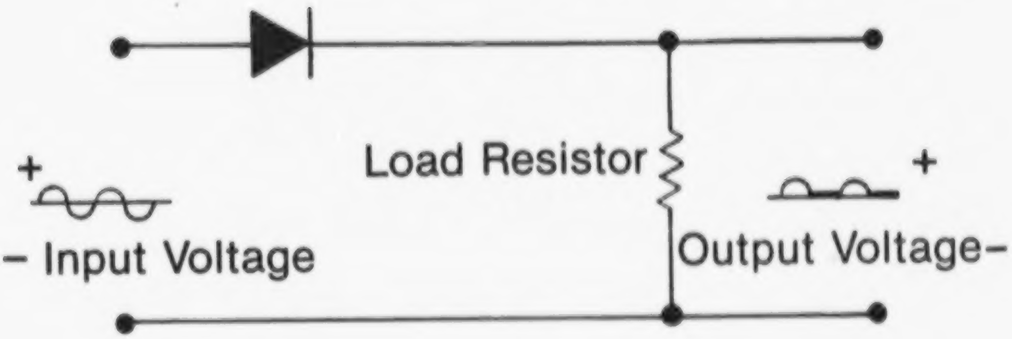
Forward Bias

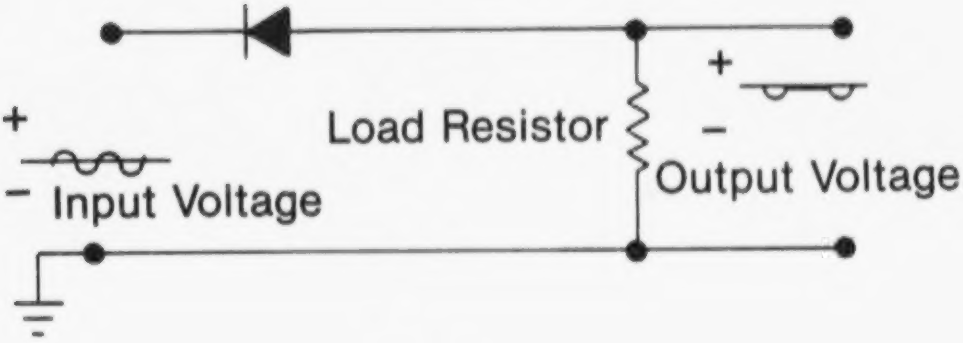

Narrow Potential Barrier
+ Positive Voltage
– Negative Voltage
Electron Flow

Reverse Bias

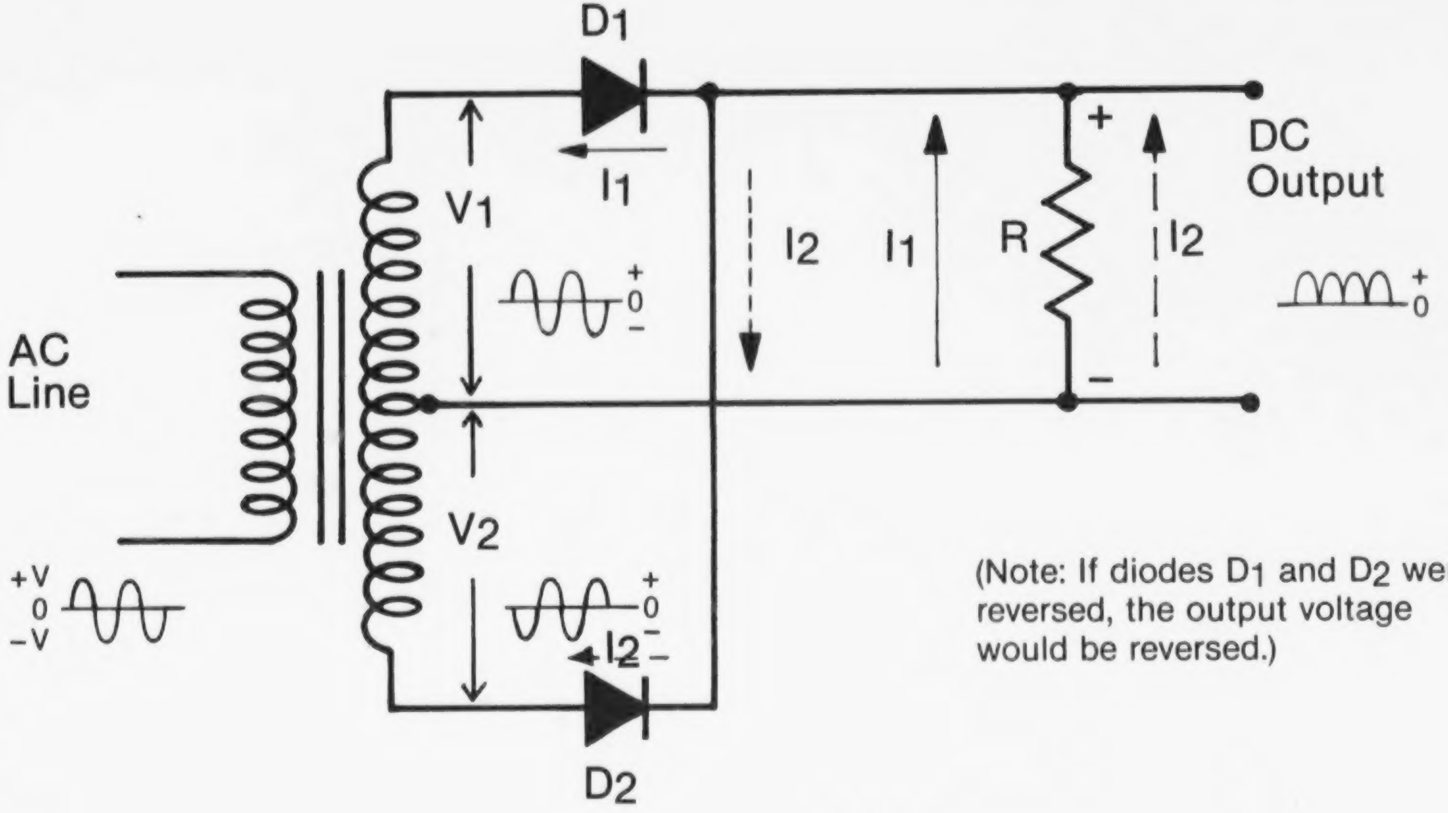

Wide Potential Barrier
– Negative Voltage
+ Positive Voltage

Half-Wave Rectifier Circuits


+
– Input Voltage
Load Resistor
+
Output Voltage–

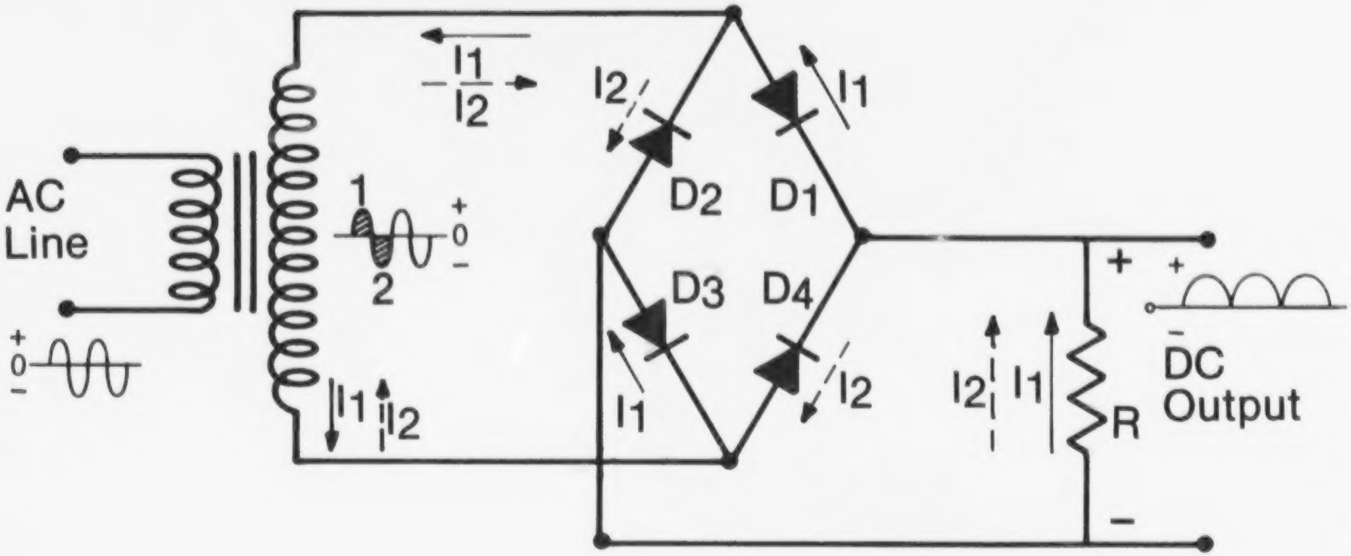

+
– Input Voltage
Load Resistor
+
–
Output Voltage

Full-Wave Rectifier


D1
I1
V1
I2
I1
R
+
−
I2
DC Output
AC Line
+V
0
−V
V2
I2
D2

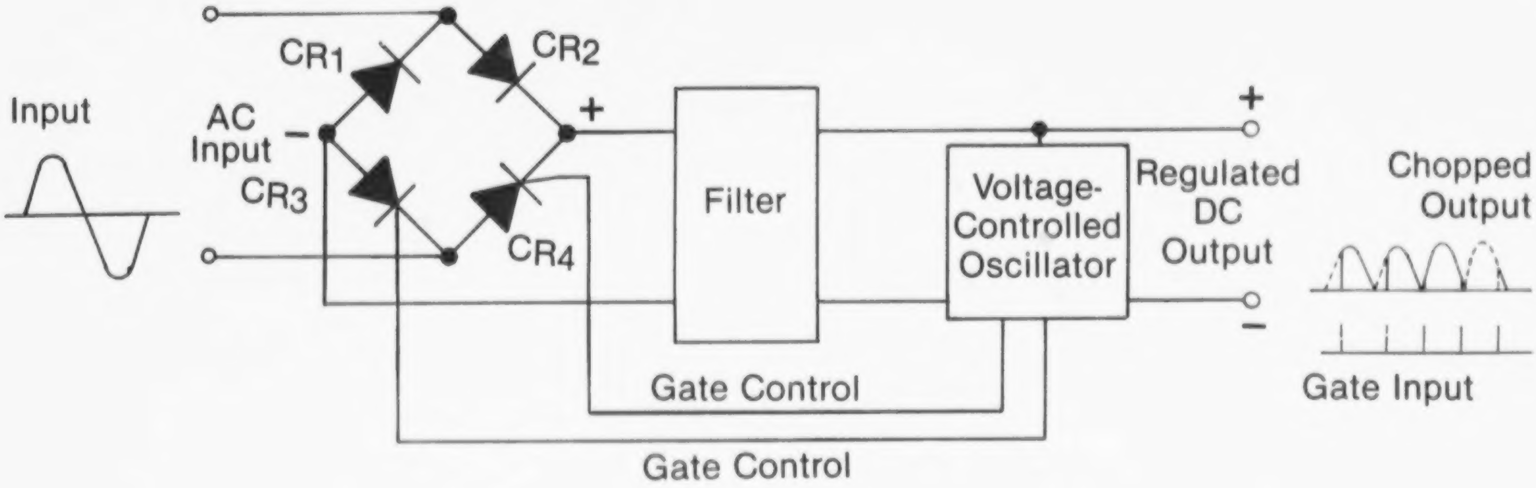
(Note: If diodes D_1 and D_2 were reversed, the output voltage would be reversed.)

Full-Wave Bridge Rectifier


AC
Line
+
0
−
I1
I2
1
2
+
0
−
D2
D1
D3
D4
I2
I1
I1
I2
I1
I2
I2
I1
R
+
−
+
−
DC
Output

(NOTE: If each diode were reversed, the output voltage would be reversed.)

Silicon Controlled Rectifier

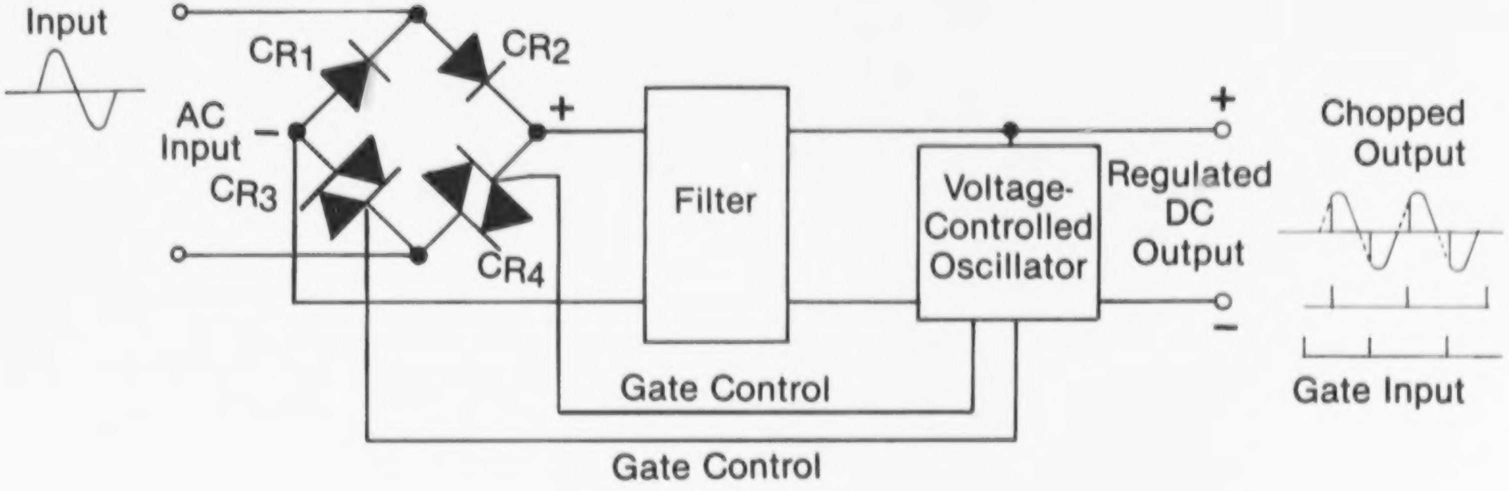


Input
AC Input
–
+
CR1
CR2
CR3
CR4
Filter
Voltage-Controlled Oscillator
+
–
Regulated DC Output
Chopped Output
Gate Input
Gate Control
Gate Control

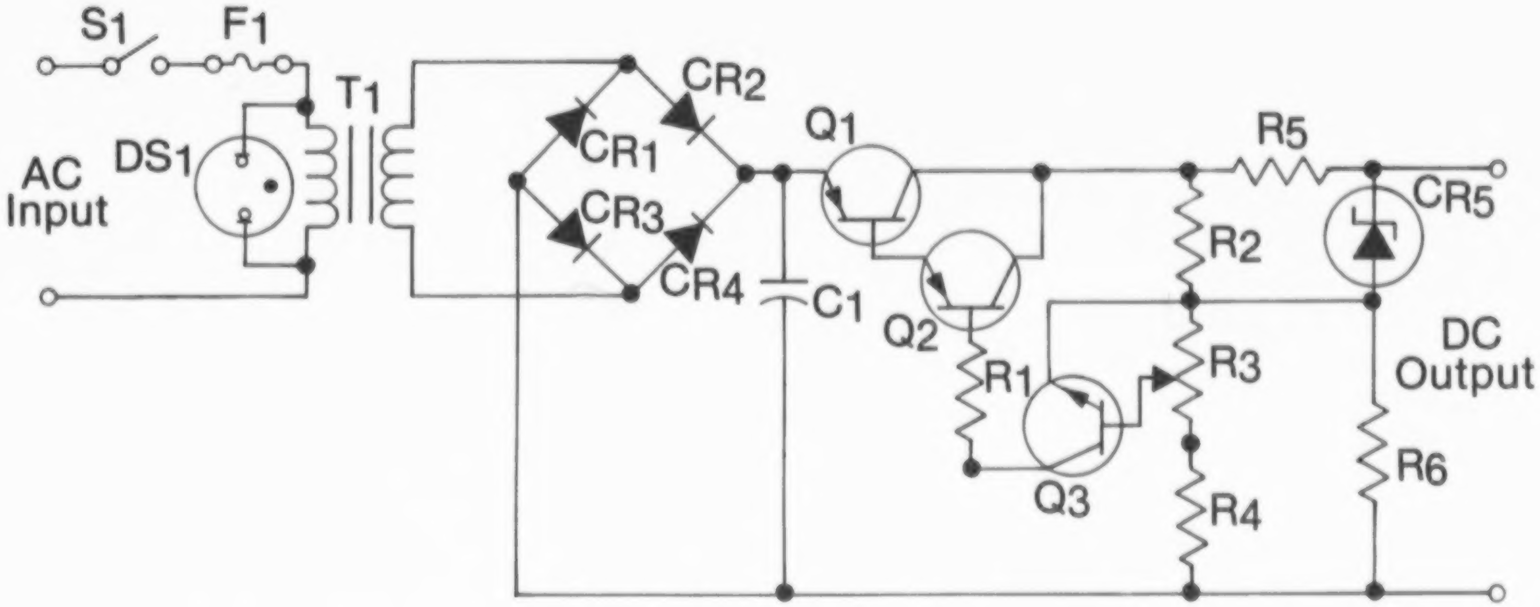
359

360

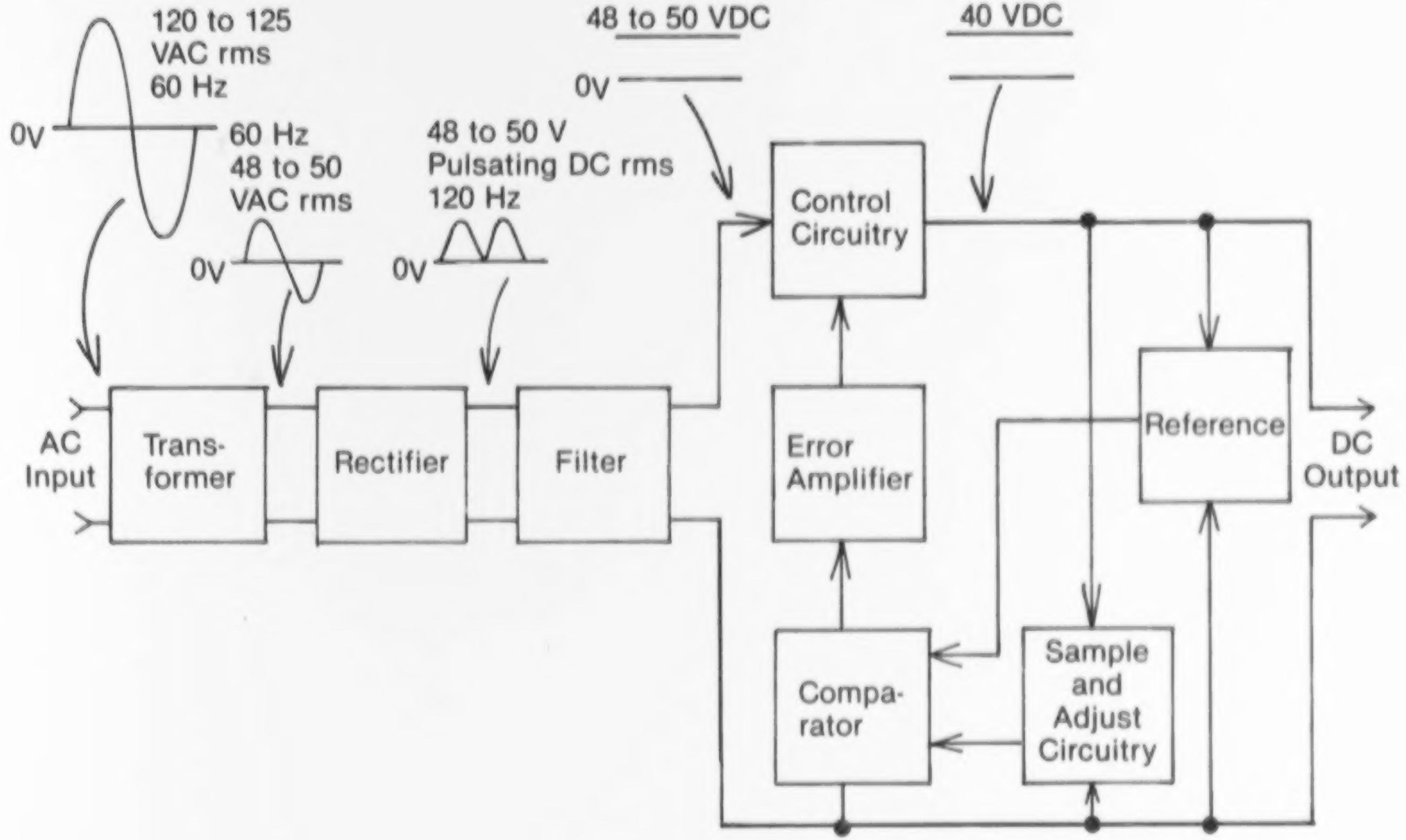
Triac Controlled Power Supply


Input
AC Input
CR1
CR2
CR3
CR4
+
−
Filter
Voltage-Controlled Oscillator
+
Regulated DC Output
−
Chopped Output
Gate Input
Gate Control
Gate Control

Simple Regulated Power Supply


S1
F1
T1
AC Input
DS1
CR1
CR2
CR3
CR4
C1
Q1
Q2
Q3
R1
R2
R3
R4
R5
R6
CR5
DC Output

Regulated Power Supply Block Diagram


120 to 125
VAC rms
60 Hz
0V
60 Hz
48 to 50
VAC rms
0V
48 to 50 V
Pulsating DC rms
120 Hz
0V
48 to 50 VDC
0V
40 VDC
AC
Input
Trans-
former
Rectifier
Filter
Control
Circuitry
Error
Amplifier
Compa-
rator
Sample
and
Adjust
Circuitry
Reference
DC
Output

TM 8

BE-397

BASIC POWER SUPPLIES
UNIT VI

JOB SHEET #1 — USE AN OHMMETER TO DETERMINE THE ANODE AND CATHODE OF DIODES

A. Equipment and materials needed

1. Multimeter
2. Several diodes, taped to cover any indication of which end is the cathode or anode

   (NOTE: Diodes will be furnished by instructor with bias specifications.)

B. Procedure

(NOTE: Determine the positive and negative polarity of the meter leads.)

1. Set meter controls to measure ohms.
2. Connect the leads across each diode, first in one direction, and then in the other.

   (NOTE: Recall that the cathode accepts electron flow, and in the forward-biased direction, the cathode connects to the negative. Use this characteristic to determine which ends of the components are the cathodes.)

3. Align diodes on workbench with cathodes all pointing away from you.

   (NOTE: Discuss your results with your instructor.)

4. Disconnect ohmmeter.
5. Return equipment and materials to their proper storage area.

BASIC POWER SUPPLIES
UNIT VI

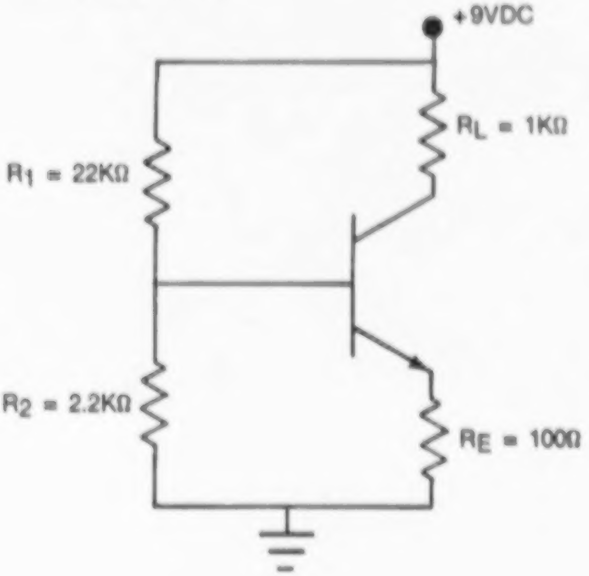
JOB SHEET #2 — CHECK TRANSISTORS FOR PROPER OPERATION

A. Equipment and materials needed

1. Multimeter
2. 2N3904 transistor
3. 1KΩ¼W resistor
4. 100Ω¼ resistor
5. 22KΩ¼ resistor
6. 2.2KΩ¼ resistor
7. 9-volt power supply
8. Protoboard and hookup wire (or equivalent)

B. Procedure

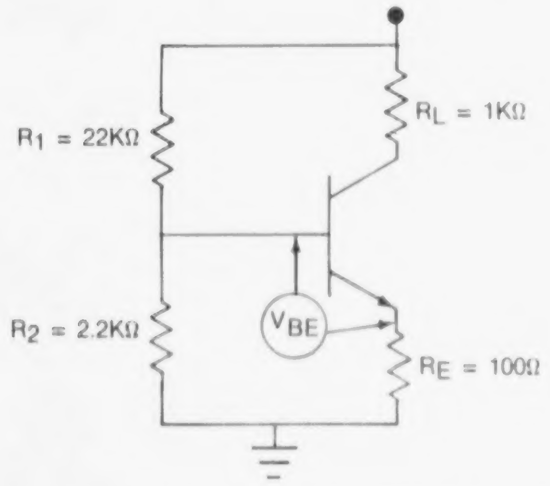
1. Connect the following circuit:



JOB SHEET #2

2. Turn the power on.

3. Measure the base-to-emitter (V_{BE}) voltage as shown below.



(NOTE: If V_{BE} is zero, the base-emitter junction is short-circuited. If V_{BE} is 0.8V or higher the junction is probably open.)

4. Measure the voltage across the load resistor.

(NOTE: If the voltage drop across RL is zero, then the current is zero. This may indicate an opening in the transistor. If there is an excessive voltage drop across RL, short-circuit the base-to-emitter voltage and remeasure V_{RL}. If the voltage is still excessive, the transistor collector is probably short-circuited.)

5. Return equipment and materials to their proper storage area.

BASIC POWER SUPPLIES
UNIT VI

JOB SHEET #3 — CONSTRUCT AND TEST A HALF-WAVE RECTIFIER CIRCUIT

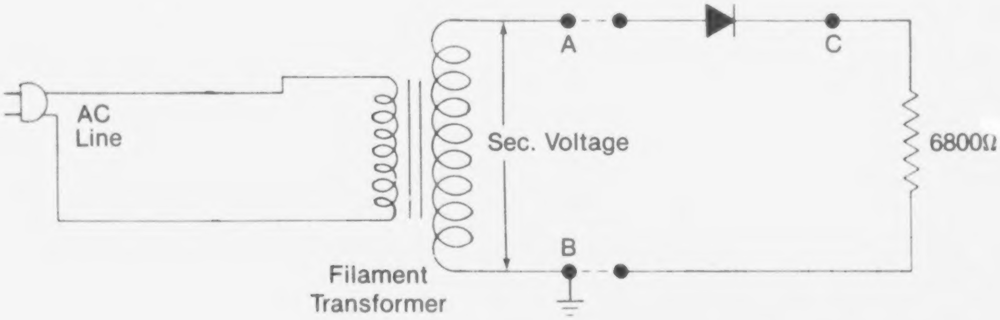
A. Equipment and materials needed

1. Low power filament transformer (120V Primary)
2. Silicon diode, 1N4004 or equivalent
3. 6800 Ohm, ½ Watt resistors
4. Multimeter
5. Oscilloscope
6. Graph paper

B. Procedure

(CAUTION: Dangerous voltage levels are present during this procedure. Check with your instructor regarding safety procedures.)

1. Connect the multimeter (set for AC) to secondary of the filament transformer.
2. Plug the filament transformer into the line voltage and measure the secondary voltage at points A and B.
3. Turn off the power.
4. Connect the following circuit to the secondary of the filament transformer.



JOB SHEET #3

5. Turn the power on.

6. Measure the voltage between points A and B and record this below as the AC input voltage.

7. Measure and record the DC output voltage between points B and C with the multimeter.

8. Using the oscilloscope, observe and make a scale drawing below of the AC input voltage (A to B) and the DC output voltage (C to B).

9. Calculate the average DC output voltage and compare it to the measured DC output voltage.

10. Have your instructor check your calculations and drawing.

DATA:

Measured voltage A to B ______ V_{rms} (Input)

Measured voltage B to C ______ V_{rms} (Output)

Calculated output voltage ______ V_{dc}

11. Return equipment and materials to proper storage area.

BASIC POWER SUPPLIES
UNIT VI

JOB SHEET #4 — CONSTRUCT AND TEST A FULL-WAVE BRIDGE RECTIFIER CIRCUIT

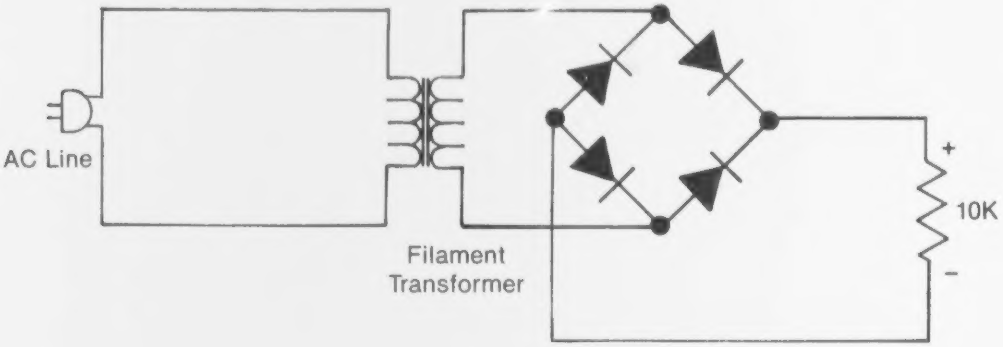
A. Equipment and materials needed

1. Filament transformer (110V primary, 12V secondary)
2. Four silicon diodes IN4004 or equivalent
3. 10K, 1W resistor
4. Multimeter
5. Oscilloscope
6. Graph paper

B. Procedure

(CAUTION: Dangerous voltage levels are present during this procedure. Avoid shock hazards.)

1. Construct the circuit shown below but do not connect power at this time.



2. Adjust the multimeter for the proper AC voltage scale.

   (NOTE: Have your instructor check your circuit.)

3. Connect the multimeter across the secondary of the power transformer.
4. Apply power to the circuit.

JOB SHEET #4

5. Read and record the DC voltage across the 10K load resistor.

6. Connect an oscilloscope across the filament transformer secondary and observe and sketch the waveform.

7. Connect an oscilloscope across the 10K load resistor and observe and sketch the waveform.

8. Calculate the average DC output voltage and compare with the measured DC output voltage.

9. Have your instructor check your calculations and sketch.

DATA:

Measured voltage A to B ______ V_{rms}

Measured voltage B to C ______ V_{dc}

Calculated output voltage ______ V_{dc}

10. Return equipment and materials to proper storage.

BASIC POWER SUPPLIES
UNIT VI

JOB SHEET #5 — CONSTRUCT AND TEST A CAPACITOR FILTER CIRCUIT

A. Equipment and materials needed

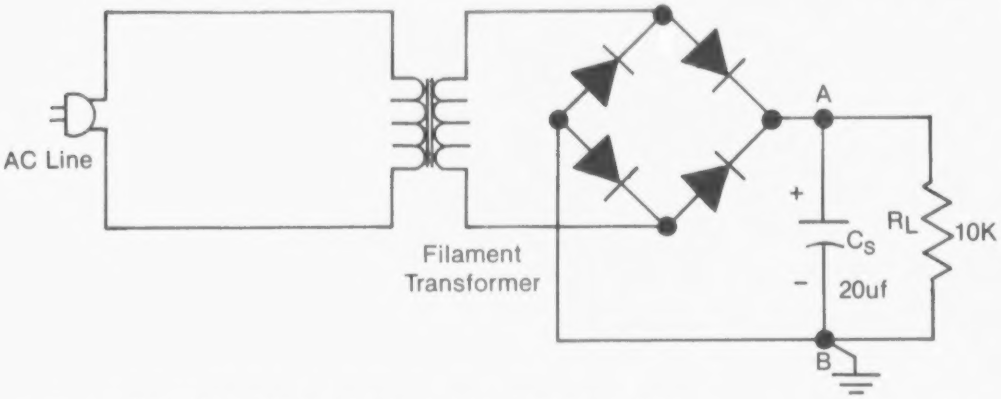
1. Low power filament transformer (120V primary)
2. Four-silicon diodes 1N4004 or equivalent
3. One-10K, 1/2 watt resistor, One-1K, 1/2 watt resistor, one-20 μF capacitor, 25 WV_{DC} or greater
4. Multimeter
5. Oscilloscope
6. Graph paper

B. Procedure

(CAUTION: Dangerous voltage levels are present during this procedure. Avoid shock hazards.)

1. Construct the circuit shown below but do not connect power at this time.

   (NOTE: Do not connect the capacitor at point A and B at this time.)



2. Adjust the scale for the proper AC voltage reading.

   (NOTE: Have your instructor check your circuit.)

3. Connect the multimeter across the secondary of the filament transformer.
4. Turn on the power supply.

JOB SHEET #5

5. Read and record the DC voltage across the load resistor.

6. Connect an oscilloscope across the load resistor, observe and sketch the wave form

7. Turn off the power.

8. Connect the 20 μF capacitor at points A and B.

   (NOTE: Observe the polarity of the capacitor. Incorrect installation may damage the component.)

9. Repeat Steps 2 through 7.

10. Replace the 10K load resistor with the 1K load resistor and repeat Steps 5 through 9.

11. Compare the wave shapes and DC voltage levels of the filter and a 10K load resistor with the filter and a 1K load resistor.

12. Using the output voltage measured with the 10K load resistor as no-load voltage and the output voltage measured with the 1K resistor as full-load, compute percent voltage regulation on the table below.

$$\% \text{ Reg.} = \frac{\text{No load} - \text{load}}{\text{No load}}$$

DATA	$V_{sec.}$	V_{10K}	V_{1K}	% Reg
No filter				
With filter				

13. Have your instructor check your calculations and sketches.

14. Return equipment and materials to their proper storage area.

BASIC POWER SUPPLIES
UNIT VI

JOB SHEET #6 — CONSTRUCT AND TEST A PI-SECTION FILTER CIRCUIT

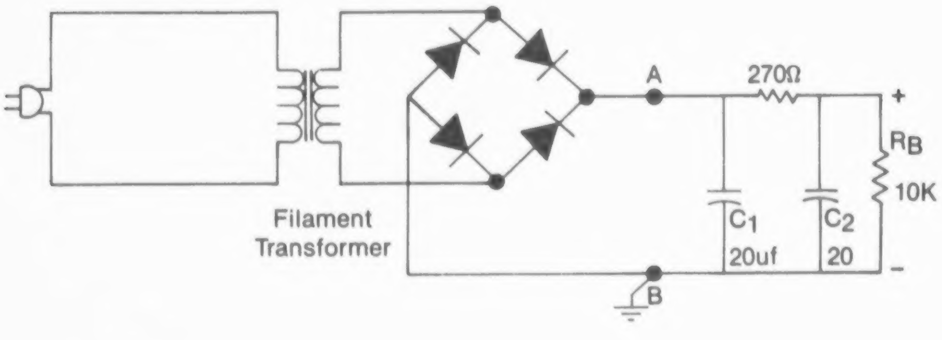
A. Equipment and materials needed

1. Low power filament transformer (120V primary)
2. Four-silicon diodes 1N4004 or equivalent
3. 10K, ½ watt resistor
4. 1K, ½ watt resistor
5. 270 ohm resistor
6. Two-20 μF capacitors $25WV_{DC}$ or greater
7. Multimeter
8. Oscilloscope
9. Graph paper

B. Procedure

1. Connect the circuit shown below but do not apply power at this time.

   (NOTE: Do not connect the Pi-section filter network at point A and B at this time.)



JOB SHEET #6

2. Turn on power supply.

   (NOTE: Have your instructor check your circuit.)

3. Read and record the DC voltage across the load resistor.

4. Connect an oscilloscope across the load resistor; observe and sketch the wave form.

5. Turn off the power.

6. Connect the Pi-section at points A and B.

   (NOTE: Observe polarity of the capacitors. Incorrect installation will cause damage to the component.)

7. Turn on the power.

8. Repeat Steps 3 through 5.

9. Replace the 10K load resistor with a 1K load resistor and repeat Steps 3 through 8.

10. Compare the wave shapes and DC voltage levels of the Pi-section filter and the 10K load resistor with the Pi-section filter and the 1K resistor.

11. Using the output voltage measured with the 10K load resistor as no-load voltage and the output voltage measured with the 1K resistor as full-load, compute percent voltage regulation on the table below.

$$\% \text{ Reg.} = \frac{\text{No load} - \text{load}}{\text{No load}} \times 100$$

DATA	V_{10K}	V_{1K}	% Reg.
No filter			
With filter			

12. Check your calculations and your sketches with your instructor.

13. Return equipment and materials to their proper storage area.

BASIC POWER SUPPLIES
UNIT VI

NAME ______________________

TEST

1. Match the terms on the right with their correct definitions.

______a. Circuit or device that provides a specific electrical output by transforming a different electrical input or converting other forms of energy

______b. Low-amplitude variation of DC power; usually results from insufficient filtering of rectified AC

______c. Circuit or device that serves to keep voltage or current output at a constant level

______d. Inductor used in a DC power supply to reduce ripple at the output

______e. Resistor connected across filter capacitors to drain charge when circuit power is turned off

______f. Controller placed in parallel to the load; bypasses excessive current and varies total current through a series resistance to control output voltage

______g. Controller placed in line with the load; controls by varying resistance to the load current

1. Series regulator
2. Choke
3. Ripple
4. Shunt regulator
5. Power supply
6. Regulator
7. Bleeder resistor

TEST

2. Sketch a P-N junction, and label the P material, the N material, the depletion region, and the barrier potential showing voltage ranges for the silicon and germanium diodes.

3. Describe biasing effects on the P-N junction.

   a. Forward bias — ______________________________

   ____

   ____

   b. Reverse bias — ______________________________

   ____

   ____

4. Draw and label the schematic symbol for a diode.

TEST

5. List three reasons for diode failure.

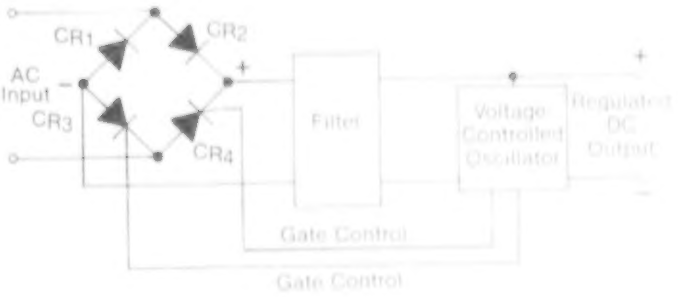
a. ______________________________

b. ______________________________

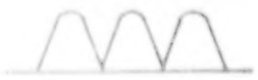
c. ______________________________

6. Match output waveforms on the right with their correct rectifier circuits.

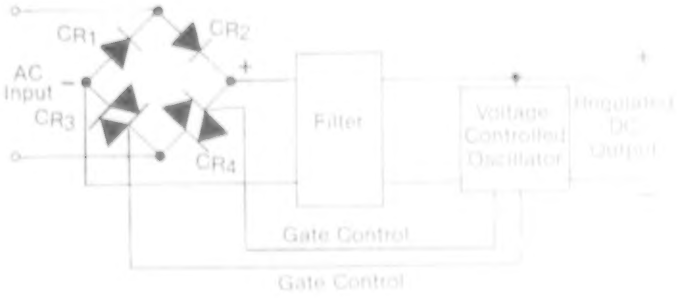
_____a. SCR


CR1
CR2
AC Input
−
+
CR3
CR4
Filter
Voltage Controlled Oscillator
Regulated DC Output
+
−
Gate Control
Gate Control

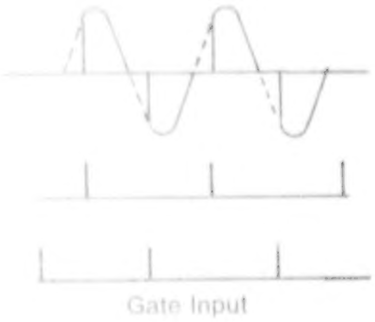
1. Output



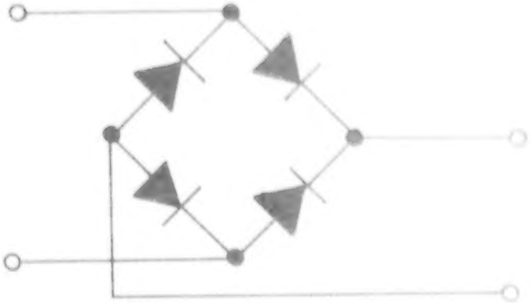
_____b. SUS


CR1
CR2
AC Input
−
+
CR3
CR4
Filter
Voltage Controlled Oscillator
Regulated DC Output
+
Gate Control
Gate Control

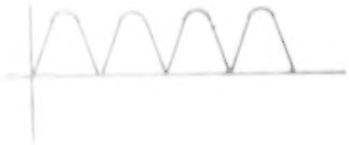
2. Chopped output



_____c. Full-wave bridge

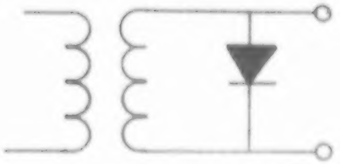


3. Output

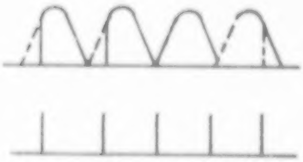


TEST

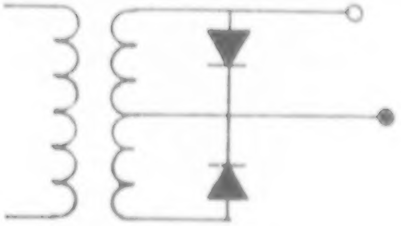
_____d. Half-wave



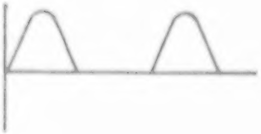
4. Chopped output



_____e. Full-wave



5. Output



7. Match power supply components on the right with their correct applications.

(NOTE: Answers may be used more than once. Some blanks may contain more than one answer.)

_____a. Used to step AC voltage up or down

_____b. Used for reference voltage or regulation (Zener)

_____c. Used as comparator of output and reierence

_____d. May be used for isolation

_____e. Used to filter pulsating DC

_____f. Used to vary AC voltage levels by switching on and off (Triac)

_____g. Used as active control element to regulate voltage or current

_____h. Required with center-tapped output for some types of rectifier circuits

1. Diode
2. Capacitor
3. Transformer
4. Transistor
5. Inductor

TEST

______i. May have multiple taps for varying output voltage

______j. Used for rectification of AC (solid-state device)

______k. Used as a controllable rectifier and frequently as a switch (SCR)

8. Match basic power supply functions on the right with their correct descriptions.

______a. Component or elements of a power supply that monitor voltages to detect error and produce a correction voltage for compensating circuitry

______b. Component or elements of a power supply that reduce ripple and noise

______c. Components of a power supply that allow for changing the output

______d. Circuitry or element of a power supply that transforms AC to pulsating DC

______e. Component or elements of a power supply that measure portion of supply voltage as feedback for controlling circuitry

______f. Circuitry or component of a power supply that changes the voltage level

______g. Components of a power supply that actually control the supply output

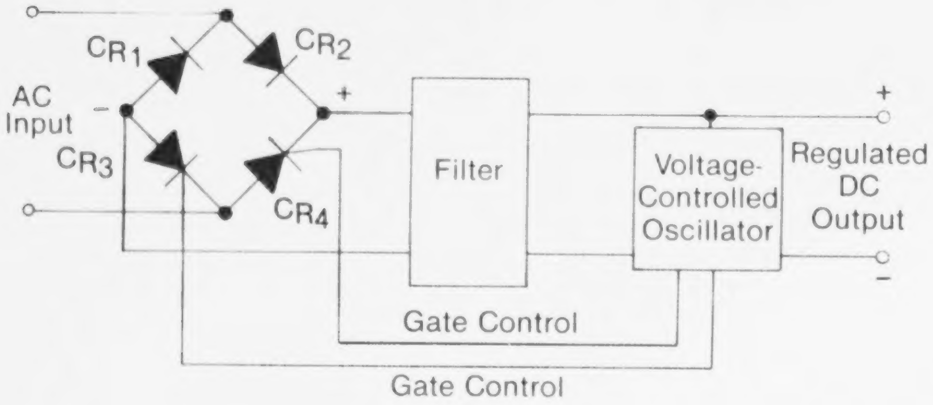
______h. Components or elements of a power supply that maintain constant voltage for the purpose of comparison by controlling circuitry

______i. Circuitry or components of a power supply that boost the error-detected correction voltage to a power level sufficient to operate the compensating circuitry

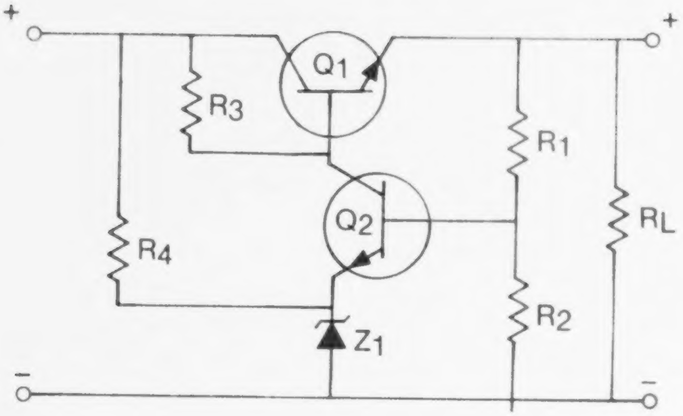
1. Sample
2. Reference
3. Comparator
4. Error amplifier
5. Control circuitry
6. Filter
7. Rectifier
8. Transformer
9. Adjust circuitry

TEST

9. Identify voltage regulator circuit schematics. Write the correct names in the blanks.

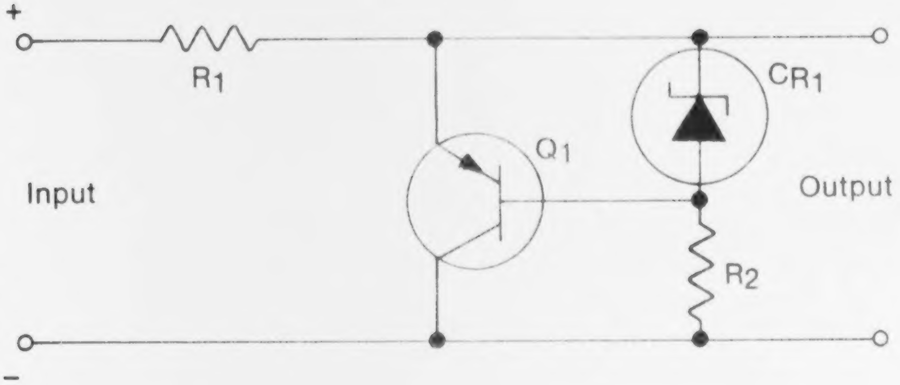

CR1
CR2
CR3
CR4
AC Input
−
+
Filter
Voltage-Controlled Oscillator
+
Regulated DC Output
−
Gate Control
Gate Control

a. ____

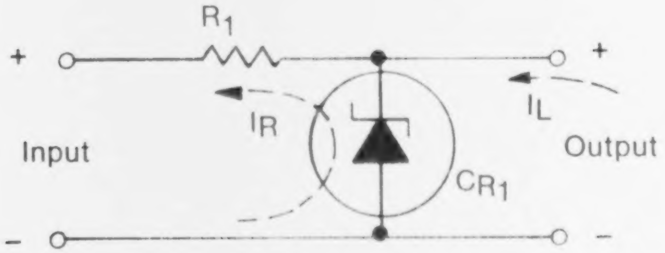

+
+
Q1
R3
R1
Q2
RL
R4
R2
Z1
−
−

b. ____

TEST



c. ____



d. ____

1) Zener diode shunt regulator
2) Transistor shunt regulator
3) Transistor series regulator
4) Thyristor regulator

10. Complete the following list of statements concerning troubleshooting the basic power supply by inserting the word(s) which best completes each statement.

a. Disconnect ____________ from power supply and check to see if problem still exists.

b. Check ____________ ____________ for charging.

c. Check ____________ ____________ for proper operation.

d. Check all resistors for proper ____________.

e. Check ____________ for proper operation.

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

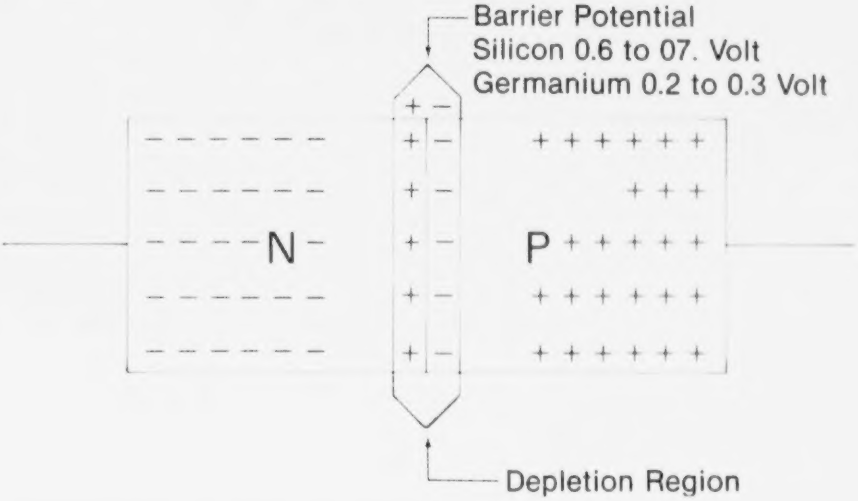
11. Demonstrate the ability to:
    a. Use an ohmmeter to determine the anode and cathode of diodes. (Job Sheet #1)
    b. Check transistors for proper operation. (Job Sheet #2)
    c. Construct and test a half-wave rectifier circuit. (Job Sheet #3)
    d. Construct and test a full-wave bridge rectifier circuit. (Job Sheet #4)
    e. Construct and test a capacitor filter circuit. (Job Sheet #5)
    f. Construct and test a Pi-section filter circuit. (Job Sheet #6)

BASIC POWER SUPPLIES
UNIT VI

ANSWERS TO TEST

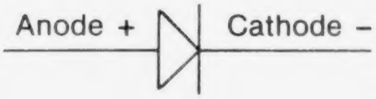
1. a. 5
   b. 3
   c. 6
   d. 2
   e. 7
   f. 4
   g. 1

2.


Barrier Potential
Silicon 0.6 to 07. Volt
Germanium 0.2 to 0.3 Volt
N
P
Depletion Region

3. a. Forward bias — Positive potential is connected to the P-type material allowing current to flow
   b. Reverse bias — Positive potential is connected to the N-type material restricting current flow

4.


Anode +
Cathode –

5. a. Heat
   b. Shock/stress
   c. Excessive current

6. a. 4
   b. 2
   c. 1 or 3
   d. 5
   e. 1 or 3

ANSWERS TO TEST

7.

a.	3	d.	3	g.	4	j.	1
b.	1	e.	2,5	h.	3	k.	1
c.	4	f.	1	i.	3		

8.

a.	3	f.	8
b.	6	g.	5
c.	9	h.	2
d.	7	i.	4
e.	1		

9. a. Thyristor regulator
   b. Transistor series regulator
   c. Transistor shunt regulator
   d. Zener diode shunt regulator

10. a. Lead
    b. Filtering capacitors
    c. Rectifier diodes
    d. Value
    e. Transistors

11. Performance skills evaluated to the satisfaction of the instructor

SEMICONDUCTOR DEVICES
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to use an ohmmeter to test for defective diodes and test and accept/reject, replace semiconductor devices. Competencies will be demonstrated by correctly performing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to semiconductor devices with their correct definitions.
2. Indicate the direction of current flow in transistors.
3. Select from a list characteristics of transistor emitters, bases, and collectors.
4. Identify the emitter, base, and collector of various transistors.
5. Distinguish between characteristics of bipolar transistors and field-effect transistors.
6. Match special semiconductor devices with their correct applications.
7. Label features of a typical dual in-line package integrated circuit.
8. Label the number-one pin on integrated circuits.
9. List advantages of integrated circuits as compared to discrete components in equivalent circuitry.
10. Complete a list of guidelines to follow when working with integrated circuits.

OBJECTIVE SHEET

11. Demonstrate the ability to:
    - a. Perform a static test of semiconductor diodes. (Job Sheet #1)
    - b. Test and accept/reject, replace light sensitive devices. (Job Sheet #2)
    - c. Test transistors. (Job Sheet #3)
    - d. Test and accept/reject, replace silicon-controlled rectifiers. (Job Sheet #4)

SEMICONDUCTOR DEVICES
UNIT VII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate the proper way to test transistors.
2. Demonstrate the proper way to handle integrated circuits.
3. Use an oscilloscope to demonstrate the output waveform of the SCR, UJT, and Triac.
4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

A. Objective sheet

B. Suggested activities

C. Information sheet

INSTRUCTIONAL MATERIALS INCLUDED IN THIS UNIT

D. Transparency masters

  1. TM 1 — PNP Transistor Majority Current Carriers
  2. TM 2 — Various Transistor Cases
  3. TM 3 — Special Semiconductor Devices
  4. TM 4 — Special Semiconductor Devices (Continued)
  5. TM 5 — Features of a Typical Dual In-Line Package Integrated Circuit

E. Job sheets

  1. Job Sheet #1 — Perform a Static Test of Semiconductor Diodes
  2. Job Sheet #2 — Test and Accept/Reject, Replace Light Sensitive Devices
  3. Job Sheet #3 — Test Transistors
  4. Job Sheet #4 — Test and Accept/Reject, Replace Silicon-Controlled Rectifier

F. Test

G. Answers to test

REFERENCES USED IN DEVELOPING THIS UNIT

(NOTE: The following is a list of references used in completing this unit.)

A. Harwick, Jim. *General Industrial Electronics*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

B. Willison, Neal and James Shelton. *Basic Electronics II*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1981.

SEMICONDUCTOR DEVICES
UNIT VII

INFORMATION SHEET

I. **Terms and definitions**

A. Analog device — Component that operates at any voltage level within a range

B. Base — Control section that varies conductivity of the transistor

C. Break voltage — Voltage level at which a diode device will switch on and conduct current

D. Channel — Narrow path within a field-effect transistor through which conduction of current is controlled

E. Chip — Integrated circuit

F. Collector — Section of transistor in which majority current carriers are *collected* out of the device

G. Cutoff — State when all normal charge carriers stop flowing in a device

H. Depletion mode — Field-effect transistor operation in which a negative voltage on the gate repels electrons in the channel and reduced conduction

I. Depletion region — Area within semiconductor material where charge carriers are neutralized

J. Discrete device — Component composed of one functional element as opposed to an integrated-circuit device composed of many elements

Examples: Transistor, diode, silicon-controlled rectifier, resistor

K. Doping — Process of adding current-conducting impurities into crystal materials to make semiconductors

L. Drain — Electrode of a field-effect transistor corresponding to the collector of a bipolar transistor

M. Emitter — Most heavily doped section of transistor where majority current carriers travel inward, and thus are *emitted* into the device

N. Enhancement mode — Field-effect transistor operation in which a positive voltage on the gate attracts electrons into the channel and increases conduction

O. Field effect — Electromagnetic force that controls conduction in field-effect transistors

P. Frequency response — Ability of a device to amplify a frequency without distortion or attenuation

Q. Gate — Electrode of various semiconductor devices that provides control for operation

INFORMATION SHEET

R. Hardware — Circuitry, wiring, and devices of an electronic instrument or computer

S. Hybrid integrated circuit — Device in which discrete components and integrated circuits are combined into an integrated package

T. Input impedance — Total opposition to current at the input of a device

U. Integrated circuit — Device constructed of multiple segments of semiconductor materials and junctions containing the equivalent function of such discrete devices as transistor and diode junctions and resistors

V. Linear device — Component that has the same gain or reaction to the input over the operating range regardless of frequency or environmental factors such as temperature and humidity

W. Majority current carriers — Holes in the p-type semiconductor and electrons in the n-type semiconductor that transfer most of the current within a type of semiconductor material

X. Monolithic integrated circuit — Device in which active elements (such as transistors) and passive elements (such as resistors) are integrated into a continuous single component on a single substrate

Y. Output impedance — Total opposition to current at the output of a device

Z. Pinch-off voltage — Voltage from the gate to the source of field-effect transistors at which conduction of current ceases

AA. Printed circuit board (PCB) — A device that has conducting paths printed on a board

BB. Saturation — When an increase in collector voltage no longer causes an increase in collector current and with an increase in base current it no longer causes an increase in collector current

CC. Source — Electrode of a field-effect transistor corresponding to the emitter of a bipolar transistor

DD. Substrate — Base material of an integrated-circuit chip upon which the circuitry is formed

(NOTE: Some integrated circuits have a pin connection to the substrate, which drains static charges, or to references to a voltage bias.)

EE. Transistor — Solid-state semiconductor device usually having three terminals; varies conductivity according to voltage and current inputs

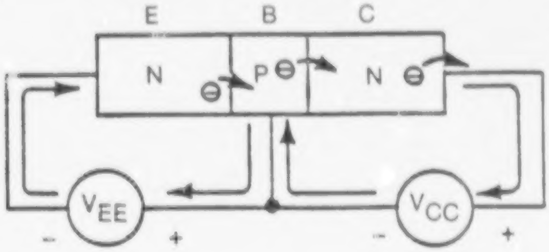
FF. Trigger — Electrical impulse used to turn devices on and off

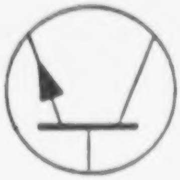
INFORMATION SHEET

II. Current flow in transistors

A. In NPN transistors, free electrons flow from emitter to base and from base to collector, causing current flow through transistor.

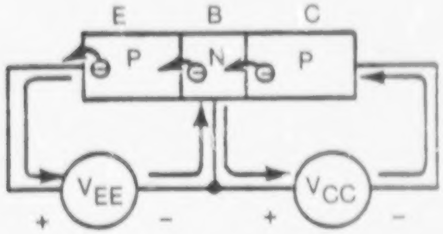
(NOTE: Because the base is narrow and lightly doped, only about 5% of the electrons flow from the emitter through the base. The remaining electrons flow through the base to the collector.)

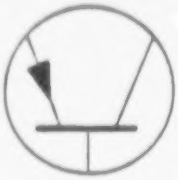




B. In PNP transistors, free electrons flow from collector to base and from base to emitter, causing current flow.

(NOTE: Because the emitter-base junction is a low resistance region, the small input signal applied to the emitter results in maximum current flow.)





III. Characteristics of transistor emitters, bases, and collectors (Transparency 1)

A. Emitters

1. Are most heavily doped section of transistor
2. Have most majority current carriers
3. Carry all current that passes into or out of transistor
4. Are indicated schematically by an arrowhead

B. Bases

1. Are constructed very narrowly to improve transistor frequency response
2. Control current flow through transistor

INFORMATION SHEET

3. Contain material opposite other two sections of transistor
4. Carry only small portion of current passing into or out of transistor
5. Are indicated schematically by a perpendicular line

C. Collectors

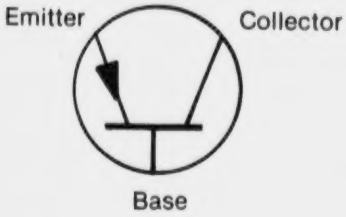
1. Are often connected to metal case of transistor
2. Carry large amount of total current into or out of transistor
3. Are indicated schematically by a diagonal line

IV. Emitter, base, and collector of various transistors

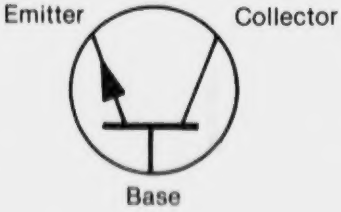
A. Circuit symbols

(NOTE: The emitter lead in both symbols is the one with the arrowhead.)

1. pnp transistor



2. npn transistor

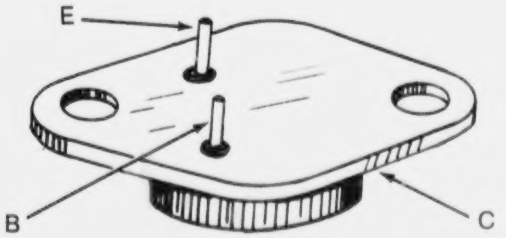


INFORMATION SHEET

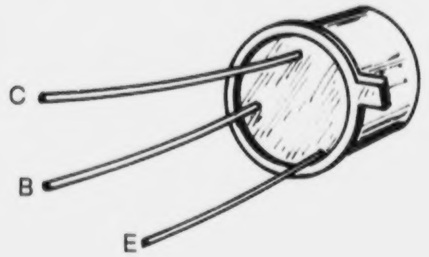
B. Leads for common transistor cases (Transparency 2)

(NOTE: There are many types of transistors cases identical to those of silicon-controlled rectifiers and field-effect transistors. Because the leads are not standard, it is best to consult a reference manual to determine the leads for the particular part number.)

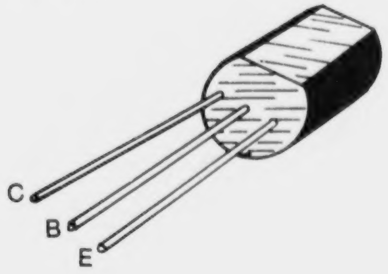
1. T0-3 case



2. T0-5 case

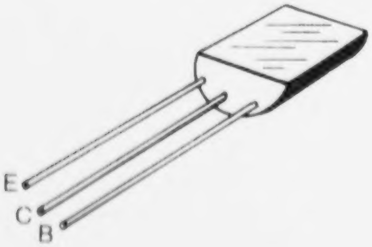


3. T0-20 case

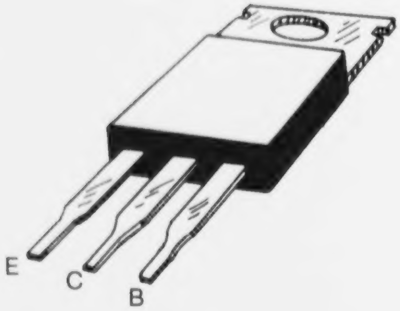


INFORMATION SHEET

4. T0-23 case



5. T0-220 case



V. Characteristics of bipolar and field-effect transistors

A. Bipolar transistors

1. Are current-controlled devices
2. Have higher frequency response
3. Have higher power ratings

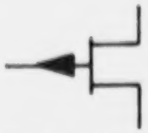
B. Field-effect transistors

1. Are voltage-controlled devices
2. Have higher input impedance
3. Produce less noise
4. Are less sensitive to heat
5. Are able to operate at higher voltage
6. Are less sensitive to radiation
7. Are more sensitive to static

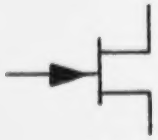
INFORMATION SHEET

VI. **Special semiconductor devices and their applications** (Transparencies 3 and 4)

A. Field effect transistor (FET) — Serves as high-input impedance device for amplifying input voltage variations applied to gate; used as amplifier

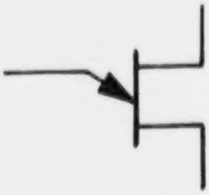


P-channel

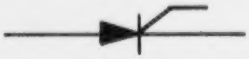


N-channel

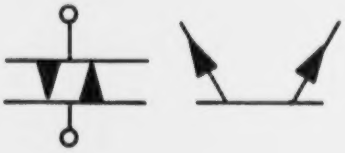
B. Unijunction transistors (UJT) — Switches on and off according to voltages and bias applied; used as oscillator or pulse generator



C. Silicon Controlled Rectifier (SCR) — Rectifies AC to DC according to timing of electrical impulse to gate lead; used as controllable rectifier and frequently as a switch

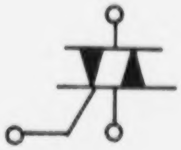


D. Diac — Switches on in either direction when voltage levels reach break voltage; used to provide triggering to AC control circuits

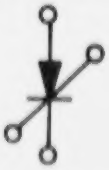


INFORMATION SHEET

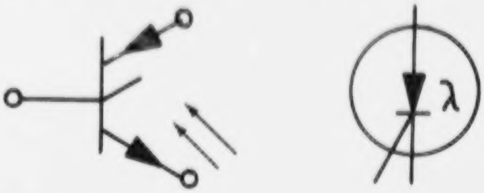
E. Triac — Switches on in either direction when gate is triggered; used to vary AC power



F. Silicon Controlled Switches (SCS) — Switches on or off by triggering either of two gates, but conducts current in only one direction; used as variable output rectifier or as DC electronic switch



G. Light Activated Silicon Controlled Rectifier (LASCR) — Switches on according to gate potential and intensity of light; used to control outdoor lighting circuits and other light-affected processes



VII. **Features of a typical dual in-line package (DIP) integrated circuit** (Transparency 5, Assignment Sheet #2)

A. Manufacturer's name or logo

B. Part number

1. Prefix

   (NOTE: The prefix varies among manufacturers.)

2. Number

   (NOTE: The number may be identical or almost identical among manufacturers.)

3. Suffix

   (NOTE: The suffix is the code for package material, temperature range, and so forth. It varies among manufacturers.)

INFORMATION SHEET

C. Date code

(NOTE: The date code is a numerical combination of the year and the week of manufacture.)

D. Notch, small indentation, or tab

E. Pins

(NOTE: Pins are numbered consecutively down one side and up the other side.)

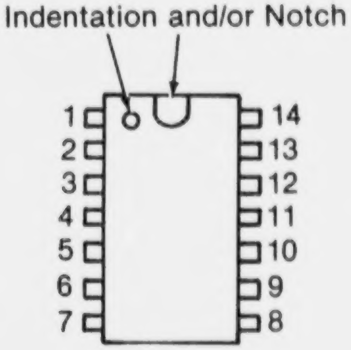
F. Distance between pin centers

G. Case

H. Top

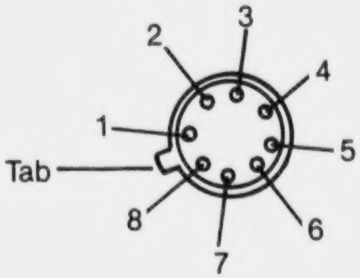
VIII. **Finding number-one pin on integrated circuits**

A. Dual in-line package (DIP) — When viewing from top with notch or indentation at top, the first top-left pin is pin number one.


Indentation and/or Notch
1
2
3
4
5
6
7
8
9
10
11
12
13
14

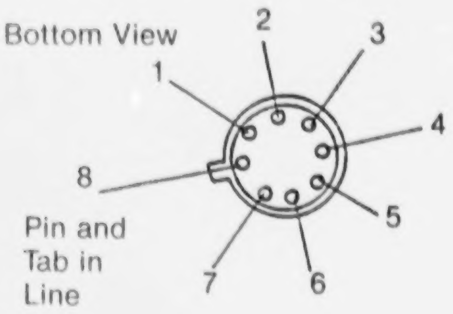
B. Case package

1. Tab between pins — When viewing from the bottom, the pin clockwise of the tab is pin number one.


3
2
4
1
5
Tab
8
6
7

INFORMATION SHEET

2. Tab in line with pin — When viewing from the bottom, the pin clockwise of the tab is pin number one.



IX. **Advantages of integrated circuits as compared to discrete components in equivalent circuitry**

A. Are more reliable

(NOTE: Less component-to-component circuitry improves reliability and reduces cost of electronic equipment.)

B. Generally require lower power

C. Are less costly

D. Are smaller, more compact, and lighter in weight

(NOTE: Integrated-circuit devices have made space travel and exploration possible by virtue of their small size and light weight. They have also made powerful computers less costly and smaller.)

E. Are simpler and faster to design and fabricate

F. Provide simplified compatibility of interconnecting circuitry

(NOTE: Integrated circuits of the same logic, such as TTL, can be readily interconnected without much concern for impedance matching, various voltage requirements, or switching-speed variations.)

X. **Guidelines to follow when working with integrated circuits**

A. Store ICs in antistatic containers.

(NOTE: A circuit may be easily destroyed by static electricity.)

B. Wear static-grounded wrist strap.

C. Use low-wattage soldering iron.

(NOTE: An integrated circuit requires special grounded and temperature-controlled soldering irons.)

INFORMATION SHEET

D. Avoid overheating components when soldering.

E. Do not use acid solder, chloride fluxes, or paste fluxes.

F. Do not remove ICs or PCBs with power on.

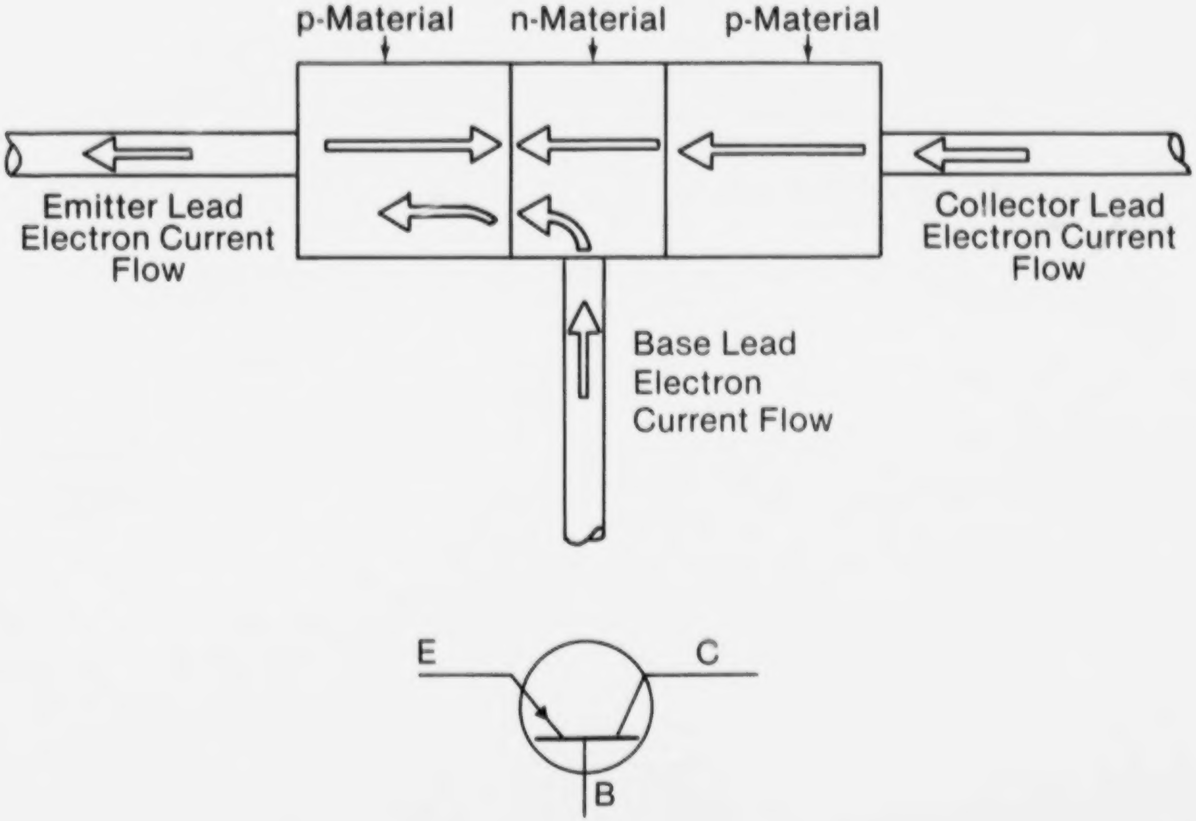
G. Do not apply signals to inputs when power is off.

H. Consult reference manual for proper voltages and connection requirements.

I. Use special test clips to avoid shorting between terminals.

J. **Do not** use analog multimeters or continuity tester to test for shorts and open circuits.

PNP Transistor Majority Current Carriers



p-Material

n-Material

p-Material

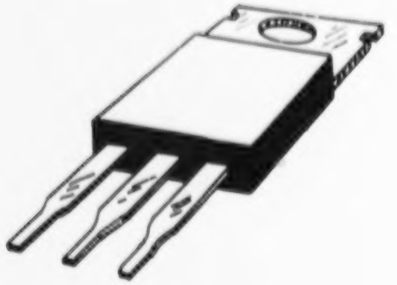
Emitter Lead Electron Current Flow

Collector Lead Electron Current Flow

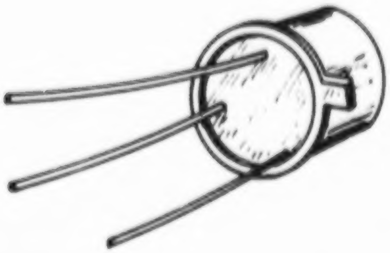
Base Lead Electron Current Flow

Various Transistor Cases

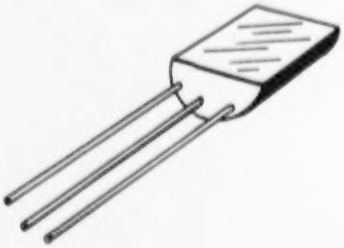
TO-220 Case



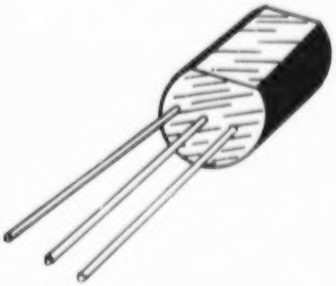
TO-5 Case



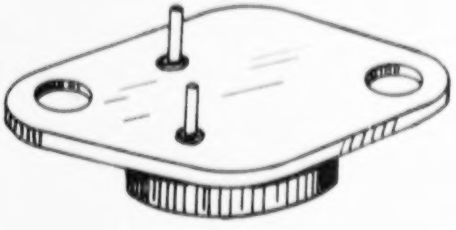
TO-23 Case



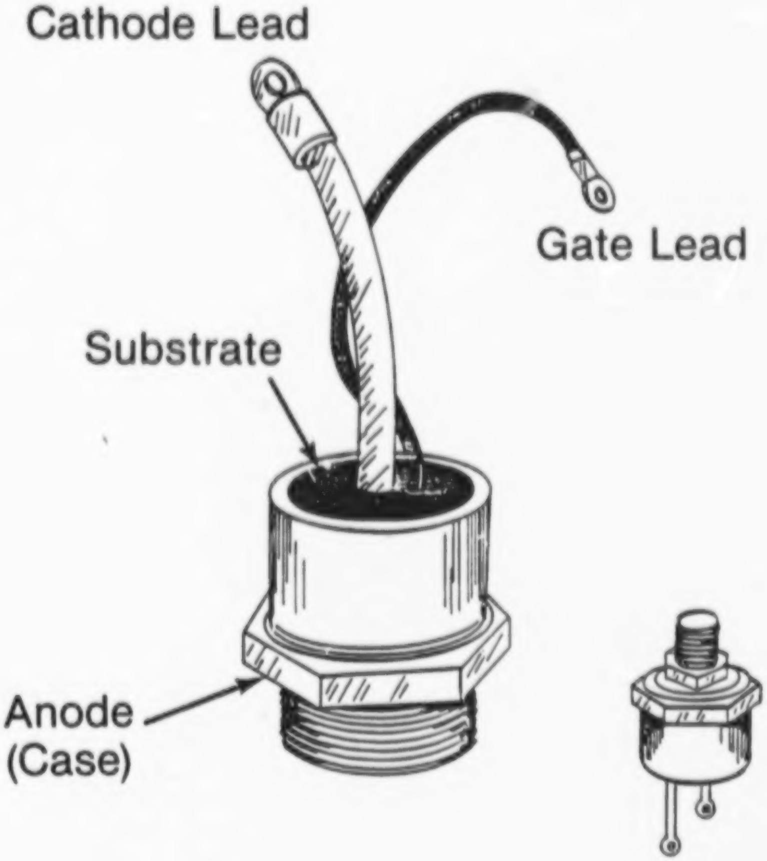
TO-20 Case

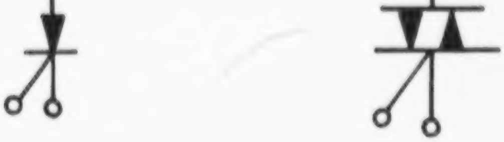


TO-3 Case



Special Semiconductor Devices

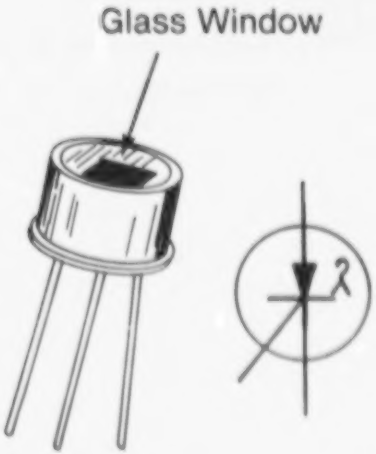

Cathode Lead
Gate Lead
Substrate
Anode
(Case)



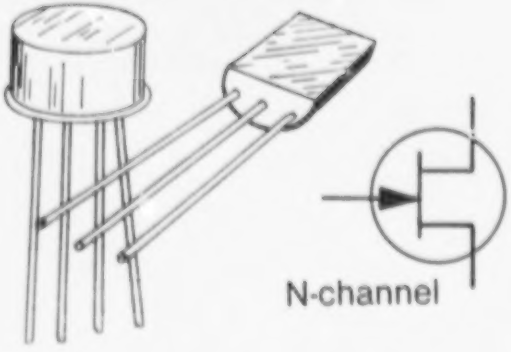
SCR or TRIAC

Special Semiconductor Devices

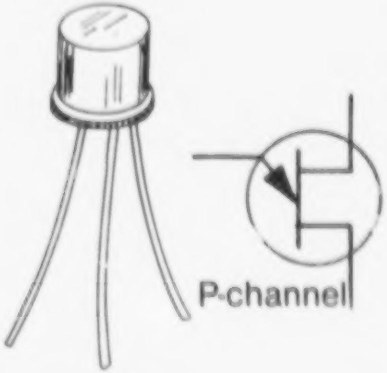
(Continued)


Glass Window

Typical LASCR



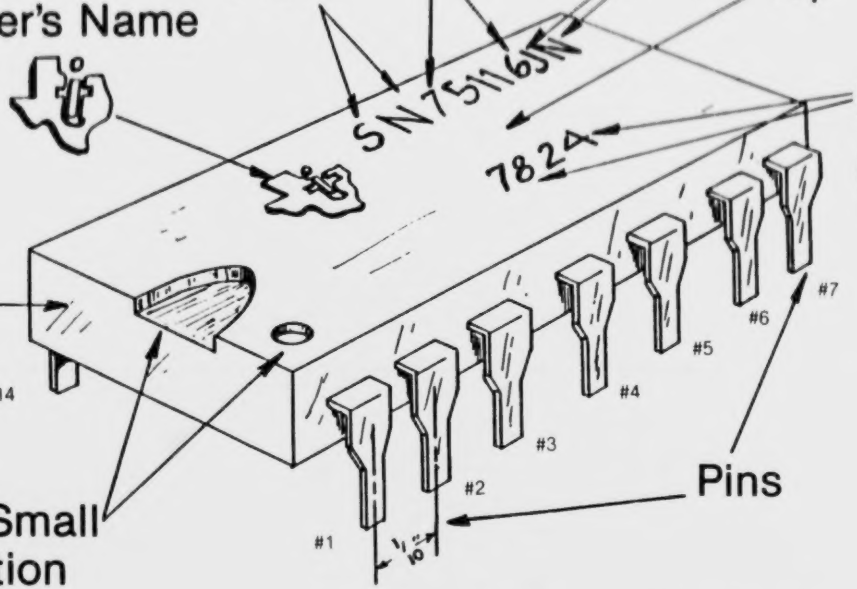
Typical FETs



Typical UJT

Solid-state devices cannot be distinguished by the cases.
Bipolar transistors, UJTs, FETs, and SCRs are often encapsulated in identical cases.

Features of a Typical Dual In-Line Package Integrated Circuit



Manufacturer's Name or Logo
(Logo for Texas Instruments is shown.)

Prefix

Number

Suffix

Top

Date Code
(78 = 1978
24 = Week 24)

Case

Pins

Notch, Small Indentation or Tab
(Device to Locate Pin Number One)

Distance Between Pin Centers
(Distance between pin centers is 2.54 mm.)

SEMICONDUCTOR DEVICES
UNIT VII

JOB SHEET #1 — PERFORM A STATIC TEST OF SEMICONDUCTOR DIODES

A. Equipment and materials needed

1. Multimeter (either digital or analog)
2. Four different types of diodes from your instructor

B. Procedure

1. Determine the polarity of your ohmmeter leads.

2. Connect the positive lead of the ohmmeter to the anode of the diode and the negative lead of the ohmmeter to the cathode of the diode.

3. Read and record the ohmmeter reading in the data table below.

   (NOTE: The ohmmeter should be on a R × 100 scale to avoid possible damage to the diode.)

4. Reverse the ohmmeter connection to the diode; read and record the ohmmeter reading.

5. Determine from the ohmmeter reading whether the diode is good or bad.

   (NOTE: A good diode will have a low ohmic reading in the forward-biased direction and a high ohmic reading when reverse biased. Typical reverse forward bias ratios would be 100 to 1.)

6. Repeat the above procedure for each of your diodes.

DATA TABLE 1 — STATIC TEST

DIODE	FORWARD RESISTANCE	REVERSE RESISTANCE	GOOD OR BAD
D_1			
D_2			
D_3			
D_4			

7. Return equipment and materials to proper storage area.

SEMICONDUCTOR DEVICES
UNIT VII

JOB SHEET #2 — TEST AND ACCEPT/REJECT, REPLACE LIGHT SENSITIVE DEVICES

A. Equipment and materials needed

1. Multimeter
2. Cadmium sulphide photocell

B. Procedure

1. Determine polarity of meter leads.
2. Set ohmmeter to the R × 1K scale.
3. Connect the meter leads to the photocell.
4. Record the ohmmeter reading.

   Resistance room light ____________

5. Cover the top of the photocell and record the ohmmeter reading.

   Resistance dark ____________

   (NOTE: Reject device if ohmmeter reading does not change.)

6. Return equipment and material to their proper storage area.

SEMICONDUCTOR DEVICES
UNIT VII

JOB SHEET #3 — TEST TRANSISTORS

A. Equipment and materials needed

1. Assortment of transistors (both signal and power types)
2. Multimeter (digital or analog)
3. Transistor tester (if available)

B. Procedure

1. Carefully examine the assortment of transistors and note the differences in size, shape, and lead arrangements.

   (NOTE: Power transistors are typically a TO-220 or a TO-3 case.)

2. Choose two signal transistors and one power transistor.

3. Determine which meter lead is positive and which is negative.

   (NOTE: Either get this from the manufacturer's instruction book or by measuring the voltage with a voltmeter.)

4. Identify the emitter, base, and collector leads.

5. Place the ohmmeter on R × 100 range.

   (NOTE: This is necessary because there may be too much voltage if the ohmmeter is placed in a high range.)

6. Determine the forward-biased emitter base junction.

   a. Place the positive ohmmeter lead on the emitter lead and the negative ohmmeter lead on the base lead.

   b. Note the resistance reading.

   c. Place the negative ohmmeter lead on the emitter and the positive ohmmeter lead on the base.

   d. Note the resistance reading.

   e. Compare the two resistance readings.

   f. Repeat Steps a through e for the collector-base junction.

JOB SHEET #3

g. From above reading, determine whether the transistor is good or bad.

h. If the transistor tested was good, state whether it is PNP or NPN.

i. If the transistor tested was bad, state where it was open or shorted.

7. If your lab has a transistor tester, following the instructions given in operations manual, check the transistor.

8. Check your findings with your instructor.

DATA CHART

EMITTER-BASE JUNCTION

R_{EB} ______________

R_{BE} ______________

COLLECTOR-BASE JUNCTION

R_{CB} ______________

R_{BC} ______________

TYPE OF TRANSISTOR ______________

9. Return equipment and material to their proper storage area.

SEMICONDUCTOR DEVICES
UNIT VII

JOB SHEET #4 — TEST AND ACCEPT/REJECT, REPLACE SILICON-CONTROLLED RECTIFIERS

A. Equipment and materials needed

1. Multimeter (digital or analog)
2. Silicon controlled rectifier

B. Procedure

1. Determine polarity of meter leads.
2. Set ohmmeter to the R × 1K scale.
3. Connect the positive meter lead to the anode and the negative meter lead to the cathode.
4. Observe a high resistance meter reading indicating non-conduction.
5. Connect a jumper wire from the anode to the gate and observe the meter reading.

   (NOTE: Reject if ohmmeter reading does not change to a low resistance indicating conduction.)
6. Remove the jumper from the anode and gate.
7. Observe the meter reading and reject if different than that of Step 5.
8. Return equipment and material to their proper storage area.

SEMICONDUCTOR DEVICES
UNIT VII

NAME ____________________

TEST

1. Match the terms on the right with their correct definitions.

(NOTE: Answers to questions a.-l. appear on this page.)

_____a. Solid-state semiconductor device usually having three terminals; varies conductivity according to voltage and current inputs

_____b. Most heavily doped section of transistor where majority current carriers travel inward, and thus are *emitted* into the device

_____c. Section of transistor in which majority current carriers are *collected* out of the device

_____d. Control section that varies conductivity of the transistor

_____e. State when all normal charge carriers are flowing in a device

_____f. When an increase in collector voltage no longer causes an increase in collector current and with an increase in base current it no longer causes an increase in collector current

_____g. Process of adding current-conducting impurities into crystal materials to make semiconductors

_____h. Ability of a device to amplify a frequency without distortion or attenuation

_____i. Holes in the p-type semiconductor and electrons in the n-type semiconductor that transfer most of the current within a type of semiconductor material

_____j. Voltage from the gate to the source of field-effect transistors at which conduction of current ceases

_____k. Area within semiconductor material where charge carriers are neutralized

_____l. Field-effect transistor operation in which a negative voltage on the gate repels electrons in the channel and reduces conduction

1. Frequency response
2. Cutoff
3. Depletion region
4. Collector
5. Pinch-off voltage
6. Saturation
7. Doping
8. Emitter
9. Base
10. Depletion mode
11. Transistor
12. Majority correct carriers

TEST

(NOTE: Answers to questions m.-y. appear on this page.)

______m. Field-effect transistor operation in which a positive voltage on the gate attracts electrons into the channel and increases conduction

______n. Voltage level at which a diode device will switch on and conduct current

______o. Total opposition to current at the input of a device

______p. Total opposition to current at the output of a device

______q. Electrical impulse used to turn devices on and off

______r. Device constructed of multiple segments of semiconductor materials and junctions containing the equivalent function of such discrete devices as transistor and diode junctions and resistors

______s. Base material of an integrated-circuit chip upon which the circuitry is formed

______t. Component composed of one functional element as opposed to an integrated-circuit device composed of many elements

______u. Component that operates at any voltage level within a range

______v. Component that has the same gain or reaction to the input over the operating range regardless of frequency or environmental factors such as temperature and humidity

______w. Circuitry, wiring, and devices of an electronic instrument or computer

______x. Integrated circuit

______y. Device in which active elements (such as transistors) and passive elements (such as resistors) are integrated into a continuous single component on a single substrate

13. Break voltage
14. Trigger
15. Analog device
16. Linear device
17. Output impedance
18. Chip
19. Substrate
20. Enhancement mode
21. Monolithic integrated circuit
22. Hardware
23. Discrete device
24. Integrated circuit
25. Input impedance

TEST

(NOTE: Answers to questions z.-ff. appear on this page.)

______z. Device in which discrete components and integrated circuits are combined into an integrated package

______aa. Electrode of a field-effect transistor corresponding to the emitter of a bipolar transistor

______bb. Electrode of a field-effect transistor corresponding to the collector of a bipolar transistor

______cc. Electrode of various semiconductor devices that provides control for operation

______dd. Narrow path within a field-effect transistor through which conduction of current is controlled

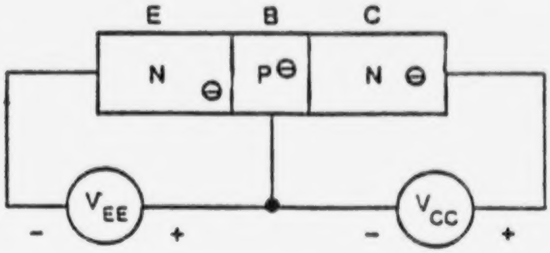
______ee. Electromagnetic force that controls conduction in field-effect transistors

______ff. A device that has conducting paths printed on a board

26. Channel
27. Hybrid integrated circuit
28. Printed circuit board
29. Field effect
30. Source
31. Drain
32. Gate

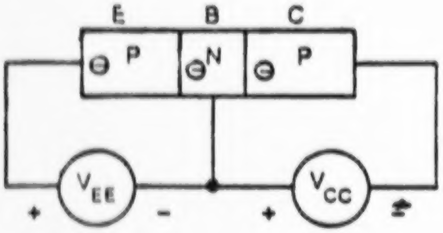
2. Indicate the direction of current flow in the following transistors by drawing arrows to indicate the direction of flow.

a.



TEST

b.



3. Select from the following list characteristics of transistor emitters, bases, and collectors. Write an "E" in the blanks before emitter, a "B" before base, and a "C" before collector.

_____a. Are most heavily doped section of transistor

_____b. Are constructed very narrowly to improve transistor frequency response

_____c. Are indicated schematically by a diagonal line

_____d. Carry large amount of total current into or out of transistor

_____e. Are indicated schematically by a perpendicular line

_____f. Have most majority current carriers

_____g. Are indicated schematically by an arrowhead

_____h. Control current flow through transistor

_____i. Are often connected to metal case of transistor

_____j. Carry all current that passes into or out of transistor

_____k. Contain material opposite other two sections of transistor

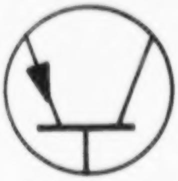
_____l. Carry only small portion of current passing into or out of transistor

TEST

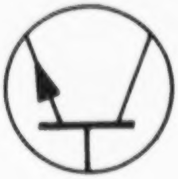
4. Identify the emitter, base, and collector of various transistors. Write the correct names in the blanks.

   a. Circuit symbols

      1) pnp transistor

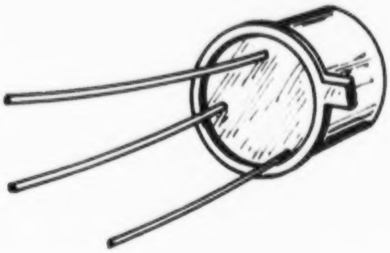


      2) npn transistor



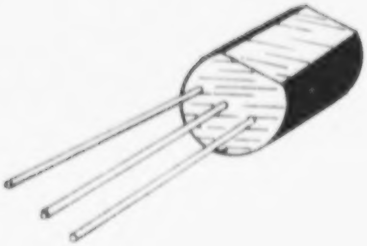
   b. Common transistors

      1) T0-5 case

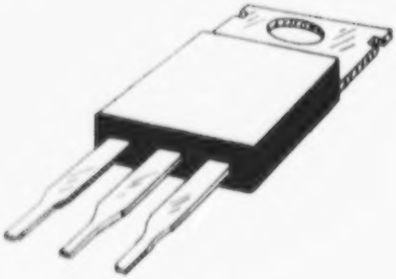


TEST

2) T0-20 case



3) T0-220 case



5. Distinguish between characteristics of bipolar and field-effect transistors. Write a "B" before bipolar characteristics, and an "FET" before field-effect characteristics.

_____a. Are voltage-controlled devices

_____b. Are current-controlled devices

_____c. Are less sensitive to radiation

_____d. Are less sensitive to heat

_____e. Have higher power ratings

_____f. Have higher input impedance

_____g. Have higher frequency response

_____h. Are able to operate at higher voltage

_____i. Produce less noise

_____j. Are more sensitive to static

TEST

6. Match special semiconductor devices on the right with their correct applications.

______a. Serves as high-input impedance device for amplifying input voltage variations applied to gate; used as amplifier

______b. Switches on and off according to voltages and bias applied; used as oscillator or pulse generator

______c. Rectifies AC to DC according to timing of electrical impulse to gate lead; used as controllable rectifier and frequently as a switch

______d. Switches on in either direction when voltage levels reach break voltage; used to provide triggering to AC control circuits

______e. Switches on according to gate potential and intensity of light; used to control outdoor lighting circuits and other light-affected processes

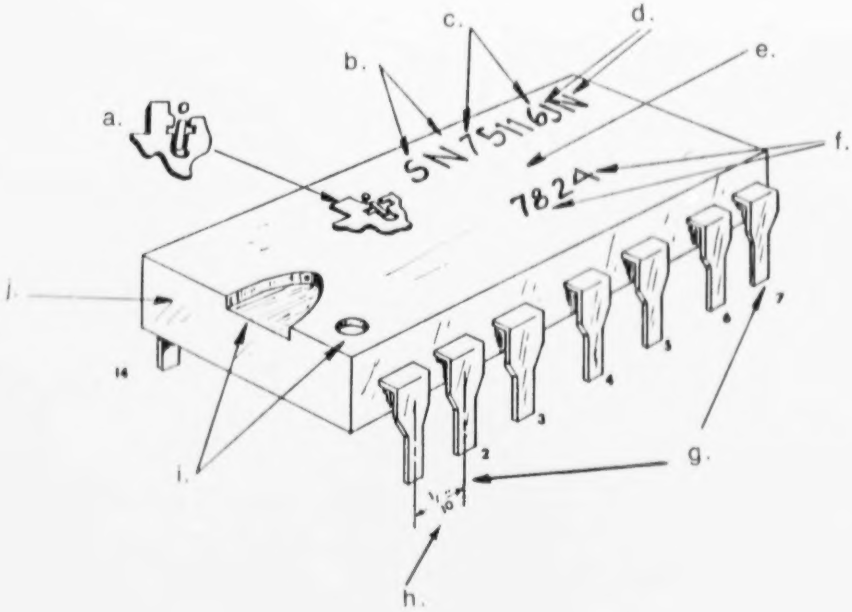
______f. Switches on in either direction when gate is triggered; used to vary AC power

______g. Switches on or off by triggering either of two gates, but conducts current in only one direction, used as variable output rectifier or as DC electronic switch

1. SCR
2. LASCR
3. UJT
4. FET
5. Triac
6. Diac
7. SCS

TEST

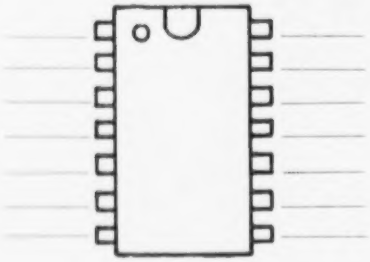
7. Label features of a typical dual in-line package integrated circuit.


a.
b.
c.
d.
e.
f.
g.
h.
i.
j.
SN75116JN
7824
1/10
1
2
3
4
5
6
7
14

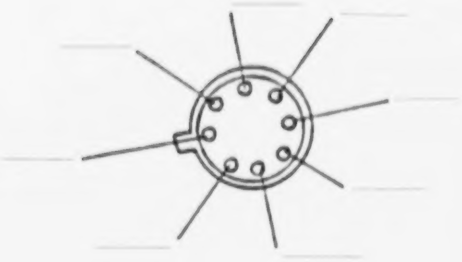
TEST

8. Label the number-one pin on integrated circuits. For each of the illustrations below, write a "1" in the correct blank.

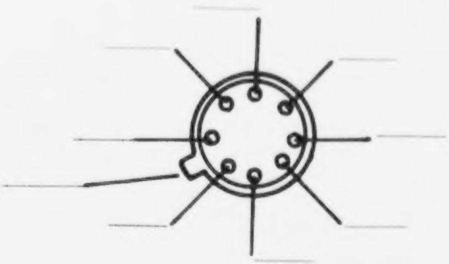
a.



b.



c.



TEST

9. List four advantages of integrated circuits as compared to discrete components in equivalent circuitry.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

10. Complete the following list of guidelines to follow when working with integrated circuits by inserting the word(s) which best complete(s) each statement.

    a. Store ICs in ____________ containers.

    b. Wear static-grounded ____________.

    c. Use ____________-wattage soldering iron.

    d. Avoid ____________ components when soldering.

    e. Do not use acid solder, chloride fluxes, or ____________ fluxes.

    f. Do not remove ICs or PCBs with power ____________.

    g. Do not apply signals to inputs when power is ____________.

    h. Consult reference manual for proper ____________ and connection requirements.

    i. Use special test clips to avoid ____________ between terminals.

    j. **Do not** use ____________ multimeters or continuity tester to test for shorts and open circuits.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Demonstrate the ability to:

    a. Perform a static test of semiconductor diodes. (Job Sheet #1)

    b. Test and accept/reject, replace light sensitive devices. (Job Sheet #2)

    c. Test transistors. (Job Sheet #3)

    d. Test and accept/reject, replace silicon-controlled rectifier. (Job Sheet #4)

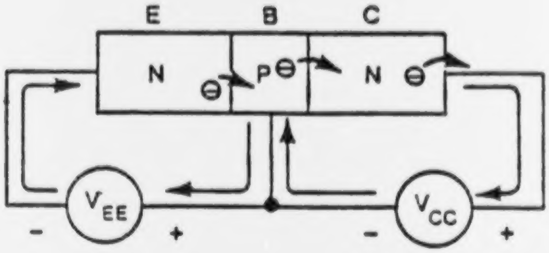
SEMICONDUCTOR DEVICES
UNIT VII

ANSWERS TO TEST

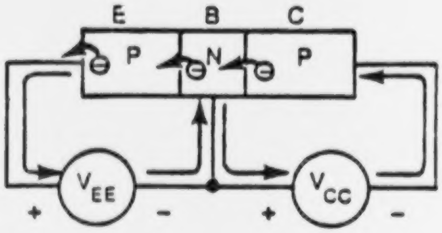
1.

a.	11	j.	5	r.	24	z.	27
b.	8	k.	3	s.	19	aa.	30
c.	4	l.	10	t.	23	bb.	31
d.	9	m.	20	u.	15	cc.	32
e.	6	n.	13	v.	16	dd.	26
f.	2	o.	25	w.	22	ee.	29
g.	7	p.	17	x.	18	ff.	28
h.	1	q.	14	y.	21		
i.	12						

2. a.



b.



3.

a.	E	g.	E
b.	B	h.	B
c.	C	i.	C
d.	C	j.	E
e.	B	k.	B
f.	E	l.	B

4. a. Circuit symbols
    1) pnp transistor
        a) Base
        b) Emitter
        c) Collector
    2) npn transistor
        a) Emitter
        b) Base
        c) Collector

ANSWERS TO TEST

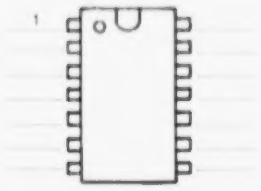
- b. Common transistor cases
    - 1) T0-5 case
        - a) Collector
        - b) Emitter
        - c) Base
    - 2) T0-20 case
        - a) Collector
        - b) Base
        - c) Emitter
    - 3) T0-220 case
        - a) Base
        - b) Collector
        - c) Emitter

5. a. FET
b. B
c. FET
d. FET
e. B
f. FET
g. B
h. FET
i. FET
j. FET

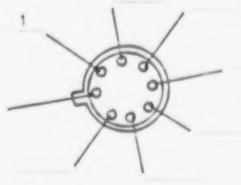
6. a. 4
b. 3
c. 1
d. 6
e. 2
f. 5
g. 7

7. a. Manufacturer's name or logo
b. Prefix
c. Number
d. Suffix
e. Top
f. Date code
g. Pins
h. Distance between pin centers
i. Notch, small indentation, or tab
j. Case

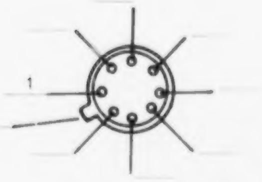
8. a.



b.



c.



ANSWERS TO TEST

9. Any four of the following:
    a. Are more reliable
    b. Generally require lower power
    c. Are less costly
    d. Are smaller, more compact, and lighter in weight
    e. Are simpler and faster to design and fabricate
    f. Provide simplified compatibility of interconnecting circuitry

10. a. Antistatic
    b. Wrist strap
    c. Low
    d. Overheating
    e. Paste
    f. On
    g. Off
    h. Voltages
    i. Shorting
    j. Analog

11. Performance skills evaluated to the satisfaction of the instructor